Centenary Program, page 406

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CONTENTS

Early Days in Radio-activity 281
SIR E. RUTHERFORD

The Anchorages of the Bridge over the Delaware River between Philadelphia and Camden 291
ALLSTON DANA AND MONTGOMERY B. CASE

The Influence of Stirring on the Rate and Course of Development 333
S. E. SHEPPARD AND FELIX A. ELLIOTT

Spectroscopy and Bohr's Theory of Atomic Structure 344
PAUL D. FOOTE

Presentation of The Franklin Medal 364

Notes from the U. S. Bureau of Standards 391

Notes from the Research Laboratory, Eastman Kodak Company 401

Notes from the U. S. Bureau of Chemistry 403

The Franklin Institute Notes 406

Book Reviews 426

Publications Received 429

Current Topics 289, 290, 332, 343, 363, 399, 400, 402, 404, 405, 429, 430

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Vol. 198 SEPTEMBER, 1924 No. 3

EARLY DAYS IN RADIO-ACTIVITY.*

BY

E. RUTHERFORD, Kt., F.R.S.

Cavendish Professor of Experimental Physics and Director of the Cavendish Laboratory, University of Cambridge; Franklin Medallist.

WHEN your Secretary asked me to write a short paper to be read before The Franklin Institute on the occasion of the formal presentation of the Medal, in the award of which you have done me so great an honour, I thought it might be of interest to give some reminiscences of my investigations of radio-activity in its early days.

The dry records of the results of the investigations are to be found in the technical journals, but it may prove of more living interest to recall some of the events and ideas that guided me in my early researches. My connection with the then infant science of radio-activity began in a very natural way as the direct consequence of my investigation on the ionization of gases by X-rays. In 1896 I was a research student in the Cavendish Laboratory, Cambridge, when Professor J. J. Thomson invited me to join him in an investigation of the temporary conductivity imparted to gases traversed by X-rays. As a result, we were able to explain the main features of the conductivity on the hypothesis that charged ions were produced in the volume of the gas by the radiation. After studying the recombination of the ions and their mobility in an electric field, it occurred to me that it would be of interest to examine the discharging action produced

* Presented at the Stated Meeting held Wednesday, May 21, 1924.

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by the rays from uranium. Henri Becquerel had discovered the radio-activity of this substance early in 1896, and had shown that the radiation discharged electrified bodies. In addition he had noted that uranium rays appeared to differ from X-rays inasmuch as they gave some evidence of refraction and polarization. After repeating these experiments of Becquerel dealing with refraction and polarization with entirely negative results, I proceeded to compare in detail the conductivity of gases by uranium rays and X-rays. It was found that they were similar in many respects and that the ions had the same mobility in an electric field. In the course of this work, I examined by the electric method the absorption of the uranium rays by matter and found that they could be separated into two types, one very easily absorbed named the *α-rays* and the other much more penetrating called the *β-rays*.

In 1898 I was appointed Professor of Physics in McGill University, Montreal. On arriving there in September, I found that R. B. Owens, your present Secretary, had just been appointed Professor of Electrical Engineering in the same institution. As newcomers interested in similar subjects, we saw much of each other and Owens, who then held the Tyndall Fellowship for Physics of Columbia University, was anxious to carry out an investigation in this subject. I suggested to him that it would be worth while to examine in detail the radio-activity of thorium which had been discovered a little earlier by Schmidt, and on which I had made some preliminary investigations in Cambridge. As Owens was occupied by his professional duties during the day, actual experimenting could only be done in the evening, and I have still a vivid remembrance of initiating him into the mysteries of the quadrant electrometer of those days. In the dry Canadian winter, the varnished floors of the laboratory became so strongly electrified that walking across the room caused marked electrostatic disturbance unless great precautions were taken in screening the connections of the electrometer. For a similar reason, the observer had to sit still in his chair during observations. To reduce these disturbances I subsequently covered the floor with thin sheets of metal connected with earth, but, as we were using a high-potential battery with one pole earthed, some disconcerting experiences of acting as a conductor for a thousand-volt battery led me to abandon this form of screening.

In the course of these experiments with thorium some very

perplexing observations were made. The conductivity in the air, produced by some compounds of thorium and particularly the oxide, was found to vary in a most erratic manner. For example, a slight draught of air, caused by opening or shutting the door of the laboratory, often altered markedly the movement of the electrometer needle. It was found that the conductivity persisted when the thorium oxide was covered with numerous sheets of paper. By passing a steady current of air through the ionizing vessel, the conductivity was much reduced. In these respects thorium compounds were entirely different from those of uranium, where the radiation was very constant.

Professor Owens left Montreal to spend the next summer in the Cavendish Laboratory and I continued observations to try to find an explanation of the anomalous results exhibited by thorium. I was at first inclined to think that this effect in air currents might be due to the presence of heavy slow-moving ions produced by the radiation, but this proved an untenable hypothesis. Finally, by passing a current of air over thoria through a long tube and by examining the conductivity at different parts of the tube, I found the radio-active effect decayed with time according to a definite law, falling to half-value in about a minute. It thus seemed clear that thoria emitted some substance which could be carried away in a gas stream. I gave the name "*emanation*" to this unknown substance. It was clear that this emanation, which was able to diffuse rapidly through paper and other porous substances, was some type of matter whose radiating power decayed with the time. Contemporaneously, I noticed that all substances remaining in contact with the emanation themselves became radio-active. This "excited radio-activity," as it was called, decayed with time according to the same laws as the emanation, but at a much slower rate, falling to half-value in about eleven hours. This activity could be concentrated on a negatively charged electrode. The active matter obtained on a platinum wire was found to be soluble in certain solutions and not in others and could be dissipated by heating the wire. These results were an indication that the activity was due to some kind of active matter which was produced by the emanation.

It appeared probable that the emanation existed in minute quantity, but it occurred to me that it might be possible to discover by diffusion methods whether it was a light or heavy substance.

For this purpose I used the radium emanation which had been found by Dorn to have a much slower rate of decay than that of thorium. One-half of a long cylinder contained air mixed with emanation. On removal of a partition, the emanation diffused into the ordinary air. The amount of emanation in the two halves at any subsequent time could be determined by electrical methods. In this way the coefficient of interdiffusion of the emanation was measured and, from comparison with the rate of diffusion of known gases, it was concluded that the emanation must have a high molecular weight of at least 100.

Passing over many other investigations, I now come to my association with Soddy, now Professor of Physical Chemistry in Oxford. After two years' research in Oxford, Soddy had been appointed Demonstrator in Chemistry in McGill. He became interested in the work I was doing in radio-activity and we agreed to join forces and attack the problem of the chemical nature of the emanation. I was to take charge of the radio-active measurement while he was to be responsible for the more chemical side of the investigation. This association proved very fruitful. By passing the emanation over various chemical reagents, we found it was quite unaffected and in this respect was quite analogous to the rare monatomic gases found in the atmosphere. Since the amount of emanation in these experiments was far too minute to give a measurable pressure or to determine its spectrum, one of the only methods of showing it to be a distinct chemical substance was to test whether it would be condensed by the action of low temperatures. We passed the emanation through a spiral cooled by solid carbonic acid but no effect was produced. We impatiently awaited the arrival and setting up of a Hampson liquid-air machine to use liquid air as a refrigerant. A steady stream of thorium emanation was passed through a lead spiral immersed in a Dewar flask. The first 20 c.c. of liquid air, which was produced in the laboratory, was poured into the flask and we had the satisfaction of noting the complete cessation of movement of the electrometer needle, showing that the emanation had been condensed by the extreme cold. By suddenly plunging the cold spiral into hot water, the emanation was released and made its presence manifest in the electrometer. The next stage was a systematic search to find whether the emanation was produced directly from the thorium or some other substance present. This

was settled by the separation of the substance known as thorium X, which was shown to give rise to the emanation. The great contrast in the physical and chemical properties of thorium X and the emanation gave us the first definite clue that radio-activity was a consequence of the successive transformation of elements and led ultimately to the enunciation of the disintegration theory of radio-activity.

In the meantime, I had been trying at intervals to see whether I could deflect the α-rays in a strong magnetic field in order to decide whether they were material in nature or a type of X-radiation. After many failures on account of the smallness of the effects, I obtained from the Curies a small quantity of radium preparation of activity about 20,000 times that of uranium. With this material, I was able to show that the α-particles were positively charged particles projected with high velocity, and the value of E/M indicated that they had a mass heavier than hydrogen. This proof of the material nature of the α-particle was very helpful in giving definiteness to the transformation theory and suggested the possibility that the helium, which is found in such large quantities in many uranium and thorium minerals, might result directly from the accumulated α-particles after they had lost their charge.

In 1903 Soddy left Montreal to work with the late Sir William Ramsay on chemical problems. In order to avoid unnecessary overlapping, we had outlined a scheme of future work before Soddy left Montreal. He was to tackle the important problem whether he could detect the growth of radium in purified uranium salts, while, as soon as sufficient radium was available, I was to examine whether helium was produced from radium. In 1903, I spent the summer in England and heard that practically pure radium bromide was being sold commercially by Professor Giesel at the very low price of about one pound per milligram. Ramsay and I both purchased some of this material. I remember well a visit I made to Soddy at University College on the day when Ramsay and he were to release the emanation from about 20 milligrams of radium to test whether they could detect its spectrum. Soddy told he would take this opportunity of noting whether any helium was released from the radium. That afternoon, the presence of helium was detected by its spectrum. I loaned them my radium to confirm the important discovery. During the summer, I visited Professor and Madame Curie in Paris and found the

latter was taking her degree of D.Sc. on the day of my arrival. In the evening, my old friend, Professor Langevin, invited my wife and myself and the Curies and Perrin to dinner. After a very lively evening, we retired about 11 o'clock to the garden, where Professor Curie brought out a tube coated in part with zinc sulphide and containing a large quantity of radium in solution. The luminosity was brilliant in the darkness and it was a splendid finale to an unforgettable day. At that time we could not help observing that the hands of Professor Curie were in a very inflamed and painful state due to exposure to radium rays. This was the first and last occasion I saw Curie. His premature death in a street accident in 1906 was a great loss to science and particularly to the then rapidly developing science of radio-activity.

I must pass over rapidly the next few years which were occupied in unravelling the long series of transformations in uranium, thorium, and actinium and in studying the nature of their radiations and their heating effects. In this work, I was greatly assisted by the coöperation of research students who came to McGill, including Doctor Godlewski from Poland, whose death two years ago is greatly to be deplored; Hahn, now professor in the Kaiser Wilhelm Institut; Rümelin, who lost his life in the first battle of Ypres, and others who came from Canada and U. S. A., of whom I must particularly mention Mrs. Pitcher (née Brooks); A. S. Eve, now director of the Physics Laboratory in McGill; Cooke, Professor in Princeton; Bronson, Professor in Dalhousie University, and S. J. Allen, Professor in the University of Cincinnati.

In 1907 I left McGill to take the post of Professor of Physics in the University of Manchester, vacated by Professor Schuster. Before leaving Montreal, I had been much interested in the discovery made independently by the late Sir William Crookes and Professor Giesel that the α-rays produced scintillations in phosphorescent zinc sulphide. There was no reason at that time to believe that each α-particle produced a scintillation, but the discovery directed my attention to the importance of finding a method for detecting a single α-particle and of counting the number emitted per second by one gram of radium. Preliminary calculations showed that the ionization current in a gas due to a single α-particle might produce sufficient effect to be detected by a very sensitive electrometer. Doctor Geiger and I attacked this problem

experimentally but without much success. It then occurred to me that the electrical effect might be greatly increased by utilizing the property of ionization by collision in a strong electric field. After some disappointments, this method proved successful and we had the satisfaction of showing that individual α-particles could be easily counted by this electric method. This allowed us to determine the number emitted per second by one gram of radium and, by measuring the positive charge carried by the α-rays, we were able to obtain a fairly accurate value of the fundamental unit of charge, *viz.*, 4.65×10^{-10}, while Millikan's later precision method gave 4.77×10^{-10} electrostatic units.

At this stage, the evidence as a whole strongly supported the view that the α-particle was a doubly charged atom of helium, but it was of great importance to settle this question definitely by a straightforward method. For this it was necessary to collect the α-particles and to show that they gave rise to helium, quite independently of the radio-active matter from which they were expelled. This might be done if a glass tube could be constructed sufficiently strong to contain a large quantity of radium emanation but so thin that the α-particles could be fired through it. I put the problem of the construction of such a tube to Mr. Baumbach, a skilful glass-blower attached to the University. After a few hours' trial, he produced the first α-ray tube of glass. With this I was able to prove definitely that the α-particles which had been fired from this tube into the walls of an evacuated glass receiver, after diffusing out, gave the complete spectrum of helium.

Unless I am to take too much of your time, I must confine myself to only a few more points of special interest. I have always, since the discovery of the nature of the α-rays, had a great interest in this type of radiation and I will now show the steps by which the α-rays were utilized to probe the inner structure of the atom and to throw light on its constitution. In our experiments on counting α-rays by the electric method, we had been troubled by the scattering of α-rays in passing through matter. Doctor Geiger made a special examination of the average scattering for small angles of deflection. I suggested to one of my Manchester students, E. Marsden, that it would be of interest to examine whether any α-particles were scattered in the backward direction from a metal plate. I did not have any reason to expect a positive result and Doctor Geiger and I were very surprised

when a considerable number of α-particles were found to be scattered through an angle of more than 90 degrees. From Geiger's experiments on the average angle of scattering by metal foils and from the laws of multiple scattering, we could not expect a detectable number of particles to appear in the backward direction. Both Geiger and I appreciated at the time that this was a very strange and remarkable result, difficult to reconcile with existing views of atomic structure. After a number of calculations, I came to the conclusion that this large angle scattering could only be explained if there were intense electric fields in the atom, due to one or more massive charged centres, and that the large deflections were produced by a single collision with such a centre. From this arose the conception of the nuclear constitution of the atom, an account of which was first given by me in 1911. The theoretical laws of scattering on this assumption were very completely verified by the careful measurements of Geiger and Marsden, published in 1913.

After this work was completed, I asked Marsden to examine whether swift hydrogen nuclei could be detected by their scintillations when α-particles bombarded hydrogen gas. In this he was quite successful. On the outbreak of war, the research laboratory was practically deserted and I took up in my spare time a further investigation of the number of hydrogen nuclei set in motion by α-rays and showed that they were greatly in excess of those to be expected on the simple scattering theory if the α-particle and hydrogen nucleus were regarded as point charges repelling each other according to an inverse square law. In the course of observations on the hydrogen nuclei, which are always given out by a radio-active source in small numbers, probably due to the presence of adventitious hydrogen, I noted that more scintillations were present in dry air and nitrogen than in dry oxygen. Since the α-particle was much the most concentrated and intense source of energy available to science, I thought it not unlikely that some of the lighter atoms might be disintegrated by an intense collision with a swift α-particle. This observation in nitrogen gave the first clue that the artificial disintegration of an atom had been effected. In subsequent work with Doctor Chadwick, we have been able to show that not only nitrogen but also boron, fluorine, sodium, aluminum and phosphorus are disintegrated by α-ray bombardment with the emission of swift hydrogen nuclei in all

directions. This advance has been largely connected with technical improvements in the microscopes for counting scintillations, due largely to Doctor Chadwick and the skilled assistance of Mr. Twyman, of Hilger and Company. In the last few months, by a modified method, we have found that all elements from fluorine to potassium can be disintegrated by α-particles. The atoms of hydrogen, helium, lithium, carbon, and oxygen show no appreciable effect under the conditions of our experiments. This, however, brings us up to later days, and I must close this brief, and I am afraid very inadequate tale, of the genesis and development of some of my researches in the field of radio-activity. If time had permitted me, I would like to have given you the history of many important new lines of work which were initiated by my co-workers in the laboratory, particularly of the fundamental researches of Moseley on the X-ray spectra of the elements and of the initial stages of Bohr's great theory of the electronic structure of the atom. It was an abiding pleasure to me to watch the unfolding of the new ideas of Moseley and Bohr which have exercised such a profound effect on the history of atomic science of our day.

Shipments of Manganese Ore in 1923.—More manganese ore was shipped in the United States in 1923 than in 1922, according to final figures given out by the Department of the Interior, in a statement prepared by the Geological Survey. Although the shipments increased more than two and one-third times—from 13,404 gross tons in 1922 to 31,500 gross tons in 1923—they were smaller than many expected that they would be under the stimulus of the tariff on manganese ore fixed by the act that went into effect September 22, 1922.

The average value per ton of the ore imported from Germany in 1922 ($90.22) and from Germany and England in 1923 ($100.37 and $126.74, respectively) are near the prices received for ferromanganese and are considerably above those received for manganese ore. It is therefore probable that the imports from those two countries reported as manganese ore represent, in part at least, some other material. The average value of all reported imports of manganese ore in 1923 was $18.80 a ton.

The imports in 1923 were the smallest since 1911 and were less than half those in 1918, when the domestic production was nearly ten times as great as in 1923. Consequently domestic production plus imports in 1923 (238,000 gross tons) was less than one-third of production plus imports in 1918 (797,000 gross tons). These figures, however, do not indicate a decrease in the requirements for manganese in 1923. Most of the manganese ore consumed in the United States is

employed in making ferromanganese and spiegeleisen, which are used in the manufacture of steel, and the steel produced in 1923 amounted to 44,943,696 gross tons as against 44,462,432 gross tons in 1918, and, except the production in 1917 (45,060,607 gross tons), was the highest ever recorded. Large stocks of manganese ore were accumulated in the United States prior to September 22, 1922, when the tariff on manganese went into effect, and the large imports of ferromanganese in 1922 and 1923 made possible the great production of steel stated with so low a total domestic production plus imports of manganese in 1923.

As usual, Montana produced by far the largest quantity of ore containing 35 per cent. or more of manganese—21,916 gross tons, more than twice the production of all the other states together. Arkansas came second, with 3768 tons. Colorado and Georgia shipped some ore in 1923 after having been completely unproductive in 1922.

The shipments of ore containing 10 to 35 per cent. of manganese decreased from 344,674 tons in 1922 to 319,666 tons in 1923, owing to a decrease in production in Minnesota and New Mexico, as the other states that produced ore of this grade in 1922 (principally Georgia and Michigan) increased their shipments, and several states, notably Arkansas and Colorado, began shipping.

The shipments of ore containing 5 to 10 per cent. of manganese increased from 251,614 gross tons in 1922 to 1,072,457 tons in 1923. The chief reasons for this immense increase are the facts that the shipments from Minnesota rose from 248,560 tons to 499,181 tons, and that the ore shipped in 1923 from the Ottawa mine of the Montreal Mining Company, in Wisconsin, and the Tilden mine of the Oliver Iron Mining Company, in Michigan, contained sufficient manganese to permit it to be classed as manganiferous iron ore instead of as straight iron ore, as heretofore.

Sand and Gravel in 1923.—The sand and gravel sold in the United States in 1923 amounted to 139,932,153 short tons and was valued at $90,903,654, according to reports made by the producers to the Department of the Interior through the Geological Survey. These figures show an increase of about 48 per cent. in quantity and 41 per cent. in value over those for 1922. There was a general increase in both the quantity and the value of all classes of this material sold except in the value for filter sand. A special canvass of railroad companies was made in 1923 in order to obtain more complete reports of non-commercial material used by them, and the figures obtained make up in part the large increase (146 per cent.) shown in the quantity of gravel used for railroad ballast. The sale of sand and gravel for use in the construction of buildings and pavements also showed a large increase. The figures for 1923 include returns obtained from 2428 sand and gravel plants, which is 443 more than the number represented by the figure for 1922.

THE ANCHORAGES OF THE BRIDGE OVER THE DELAWARE RIVER BETWEEN PHILADELPHIA AND CAMDEN.*

I. DESIGN OF THE ANCHORAGES.

BY

ALLSTON DANA, A.B., B.S.

Assistant Engineer of Design, Delaware River Bridge Joint Commission.

GENERAL PURPOSE AND FUNCTION.

THE Delaware River Bridge is to be a suspension bridge. Like other bridges of this type nearly the entire weight of the bridge itself between anchorages, a distance of six-tenths of a mile, together with the weight of the traffic passing over it, will be hung from cables. The cables will be therefore in very great tension. They will be supported vertically by the two main towers which are now completed, and the pull or tension at their ends will be resisted by the two anchorages to which they will be fastened. These anchorages are now partially constructed. When completed they will be huge concrete structures faced with granite 218 feet long, 190 feet wide, 175 feet high above ground, and with foundations extending down to rock 65 feet below ground in Philadelphia and 105 feet below ground in Camden.

To properly resist the pull of the cables the anchorages must have two essential characteristics—they must be long, and they must be extremely heavy.

The length of the anchorages was determined by the fact that the Philadelphia anchorage is located between Delaware Avenue and Front Street and has been made to occupy the entire distance between these streets.

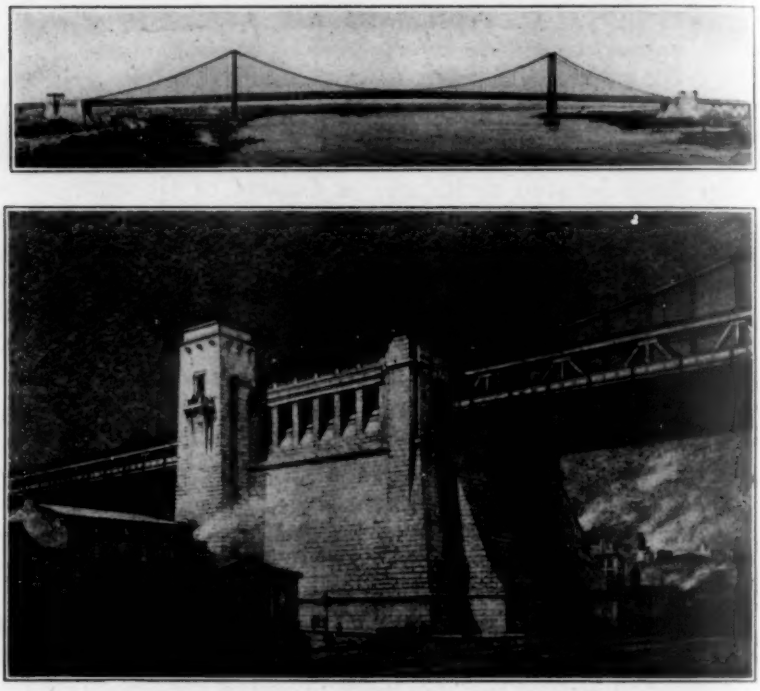
Each anchorage will weigh five or six times as much as the pull exerted on it by the cables, and the combined weight of both anchorages will be over seven times as much as the entire load supported by the cables.

The estimated maximum amount of load which the cables will ever have to carry is nearly sixty thousand tons, of which about 70 per cent. is the dead-weight of the structure and 30 per cent.

* Presented at a joint meeting of the Institute and the Philadelphia Section, American Society of Civil Engineers, held Thursday, April 3, 1924.

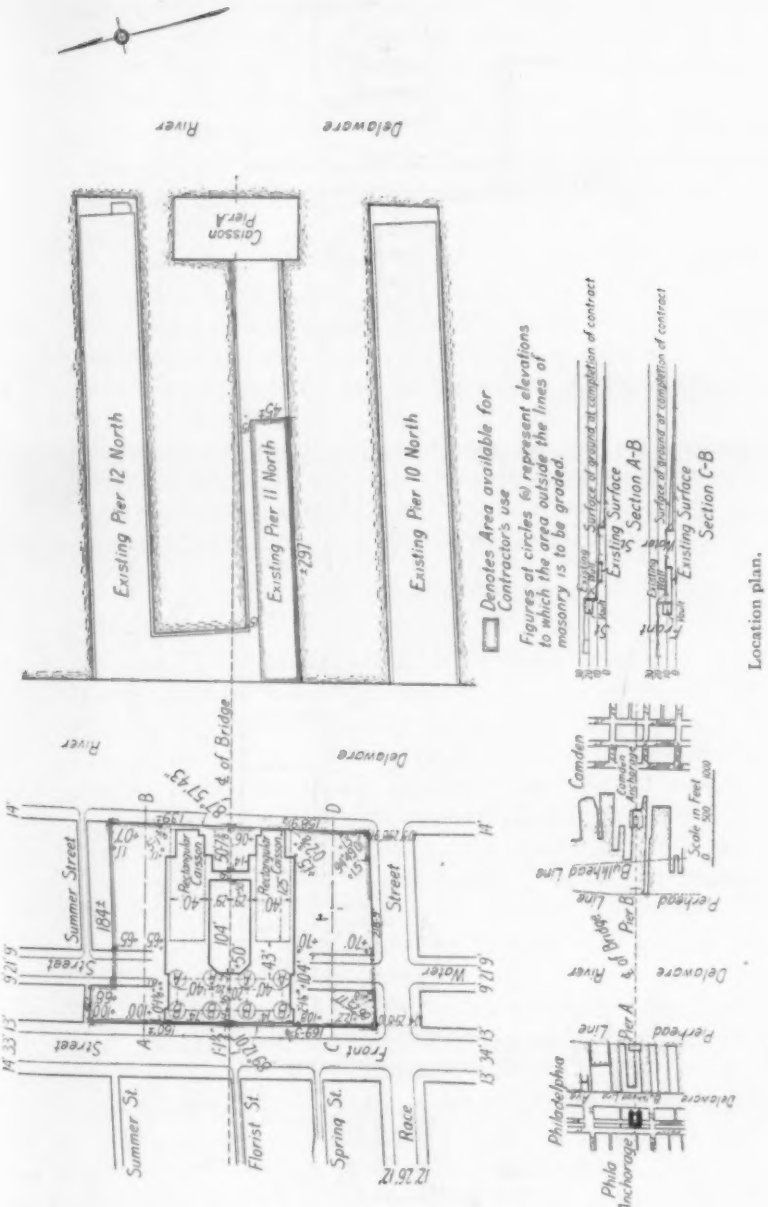
the weight of traffic. The maximum dead-weight includes the necessary structure of the bridge and also an allowance of about 14 per cent. for electric conduits and other possible future additions.

The 18,000 tons of traffic included in this estimate is based on assuming continuous lines of trolley-cars on two of the tracks, continuous lines of rapid transit trains on the other two tracks,

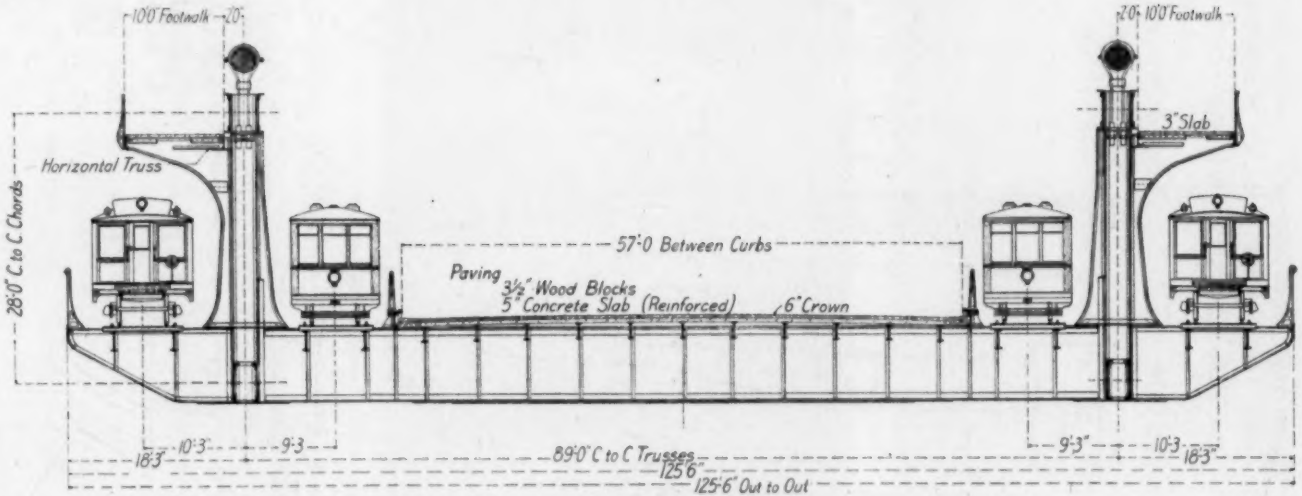


General view of bridge and Philadelphia anchorage.

the 57-foot roadway filled solidly with automobiles and trucks from end to end of the structure, and each of the 10-foot sidewalks crowded with people. To produce such a congested load there would be required 150 trolley-cars, 120 rapid transit cars, 1000 automobiles and trucks and a veritable army of pedestrians. No such congestion of traffic is likely to occur, certainly not under operating conditions, but as a possible emergency load it has been assumed in the design of the cables, the towers and the anchorages. To hold up this great volume of traffic a suspended



Location plan.



Cross-section of bridge.

structure is required which will weigh over twice as much as the traffic carried, and which will include two 30-inch diameter steel cables, each weighing nearly a ton per foot of length and each subjected to a maximum pull of 20,000 tons.

The two anchorages which will hold the ends of the cables and resist their pull will have a combined weight of over 400,000 tons or twenty-three times as much as that of the congested traffic on the bridge.

The relation between these various loads and forces is shown in the diagram on page 296. The weight of the bridge, including the live load, although uniformly distributed along its length, can be considered as concentrated at the centre of each span for the purpose of calculating the pull in the cables at the towers and anchorages, these being found by the principle of the parallelogram of forces. From these pulls the vertical load on each tower can be found by the same principle. This load, combined with the weight of the tower itself and again with the weight of the pier, gives the loads on the top and bottom of each pier.

FORCES ON THE ANCHORAGES.

In the case of the anchorages, the pull in the cables, combined with the weight of an anchorage acting through its centre of gravity gives, by the principle of the parallelogram of forces, a resultant force acting downward at a fairly steep inclination. The steepness of inclination of this resultant force and its position with respect to the bottom of the anchorage are the two main factors in the design of the anchorage considered as a whole.

In the first place the inclination of the resultant force must be sufficiently steep to prevent the anchorage from sliding forward. In other words, the weight must be great enough to produce a friction on the bottom of the anchorage foundations greater than the maximum pull of the cables.

In the second place the location of the resultant force must be such that excessive pressures will not exist between the bottom of the foundation and the underlying rock.

The average pressure on the bottom depends on the weight of the anchorage and on the bearing area of the foundation and is independent of the amount of the pull of the cables. The maximum pressure, however, may be considerably greater than the average. It will occur either at the front end or at the back end

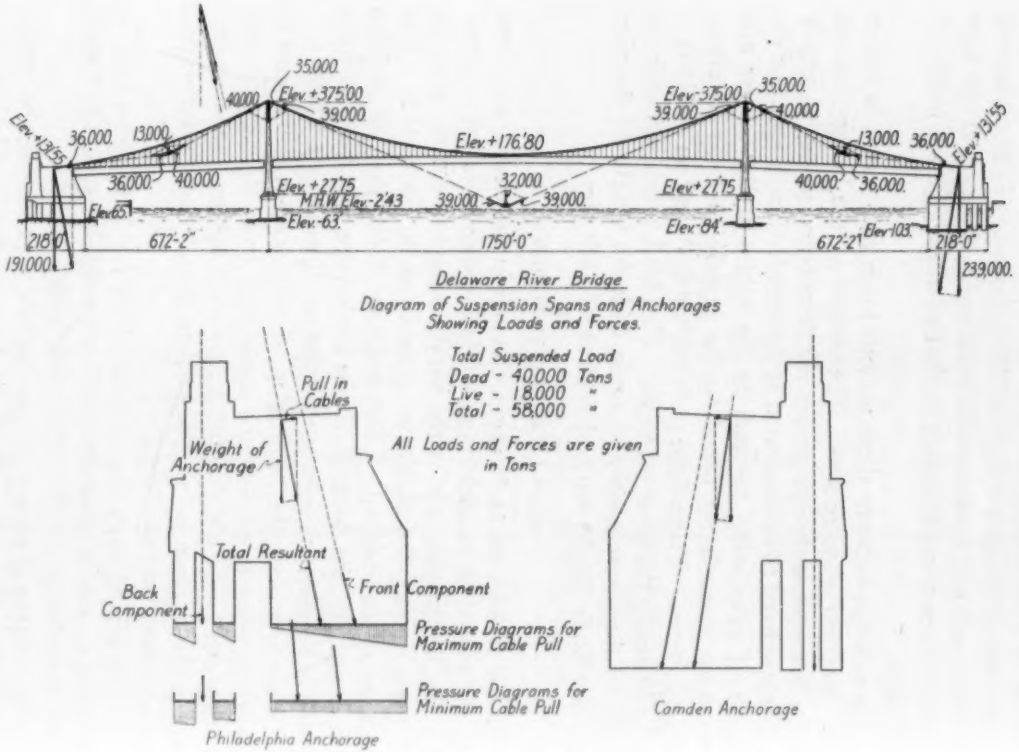


Diagram of forces on bridge.

of the foundations and depends in a general way upon the position of the resultant force at the bottom with respect to the centre of gravity of the foundation area. Thus with the maximum pull in the cables, corresponding to the maximum load on the bridge, the resultant force will intersect the bottom of the foundation quite far forward and will produce the maximum bottom pressure at the front end, while with the minimum pull in the cables, corresponding to a minimum load on the bridge, the resultant force will cut the bottom further back and will produce the maximum pressure at the back of the foundation. Obviously the range in position of the resultant on the bottom is greatly accentuated by the fact that the cable pull is applied to the anchorages at such a great height above the bottom of the foundations.

A number of factors in the design of the anchorage contribute towards keeping the resultant force in a proper position. One factor is the great weight which steepens the inclination of the resultant thereby bringing it well back from the front and reducing its range of position. Another factor is having the centre of gravity of this weight far back, thereby correspondingly keeping back the resultant force. A third factor is having the centre of gravity of the foundation bearing area well forward, thereby bringing it near to the position of the resultant. Finally, the great length of the anchorage contributes by making these last two factors more effective and by making the range of positions of the resultant relatively small.

The foundation for each anchorage is not a continuous structure from end to end, but consists of two parts. Under the front end there is a pair of long rectangular blocks, one on each side, and under the back end there is a group of eight cylinders. With an articulated arrangement like this the bottom pressures cannot be found directly in terms of the resultant force, and its eccentricity from the centre of gravity of the foundation area. This method, applicable to a continuous foundation, if applied to this case, involves the assumption that vertical shear is transferred from one part of the foundation to another through the intervening soil. But this material is not rigid enough to do this. It was necessary then to resolve the resultant force into two component forces, one being the force carried by the cylinders, the other being the force carried by the rectangular blocks. With

these component forces determined, the bottom pressures were found by considering each part of the foundation separately.

These component forces could not be found by statics, because their lines of action are not known. In other words, these forces were statically indeterminate, and to find them it was necessary to consider the probable elastic behavior of the foundations themselves, and of the anchorage above the foundations. The method used in making this elastic analysis will be given later. In the meanwhile the internal arrangement of the anchorage above the foundation will be described.

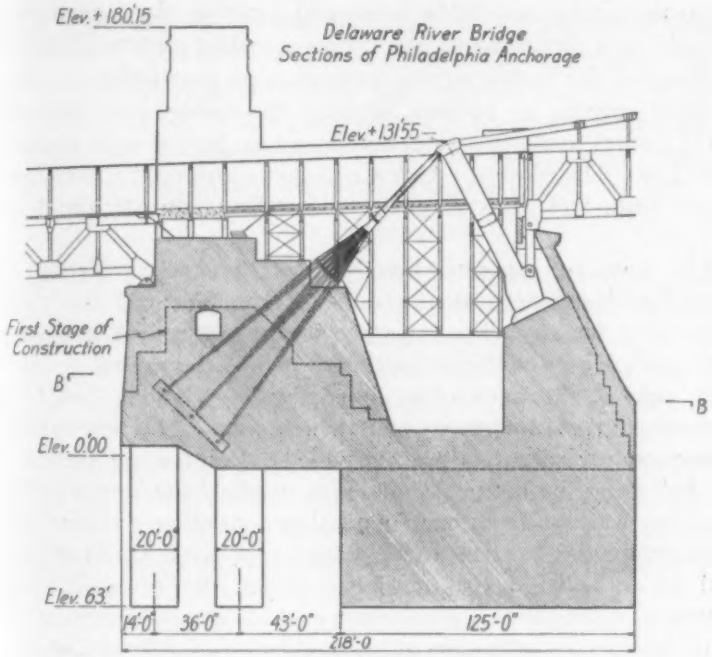
UPPER PART OF ANCHORAGE.

The length of the anchorage, together with its necessary width and height, gives a volume much greater than that necessitated by the required weight. Only the back part of the anchorage is to be filled solid with concrete. The remainder will be hollow, except for such walls, floors and buttresses as are needed for other purposes than weight only. This makes it possible to keep the centre of gravity well back as required.

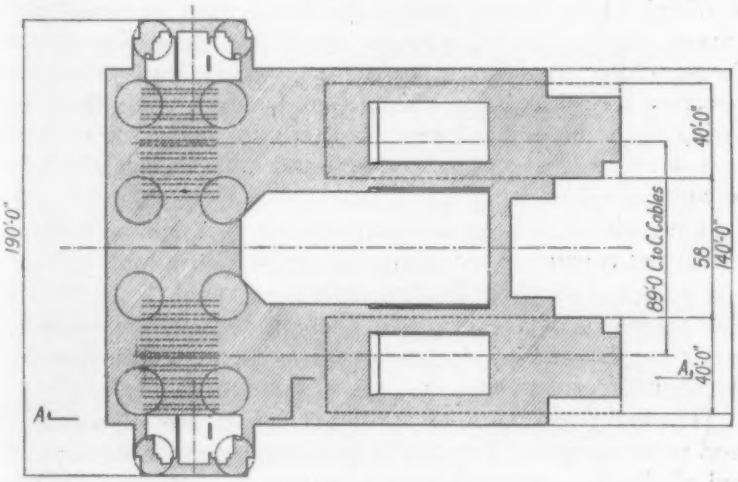
The cables will enter the anchorage at a point 130 feet above ground and at an inclination of eight degrees with the horizontal. They will bend over the top of an inclined steel tower, called the anchorage cable bent, and will pass down into the anchorage at an inclination of about forty-five degrees. The steel tower takes the kick from the cables, that is the resultant of the pull on each side, and is supported by a pair of masonry piers or buttresses, one under each leg of the tower. These buttresses are made large enough and heavy enough to take care of the inclined force, and are connected by a cross-wall which acts as a strut between them. Each buttress will be connected to the large mass at the back by two longitudinal walls, one exterior and one interior.

At a point 40 feet down from the top of the inclined tower each cable will be incased in a cast steel band the lower part of which is bell shaped, and the cable will flare out in all directions below this point. The individual cable wires, of which there are to be over 18,000 in each cable, will loop around a group of sixty-one cast steel shoes, each shoe taking 153 loops of wire. Each of these shoes will be connected by a 9-inch pin to a pair of 10-inch eyebars.

The whole group of 122 eyebars which takes the pull of one



Section A-A



Section B-B

Sectional elevation and plan.

cable passes down into the back mass of concrete, flaring out continuously, and connects to a row of nine anchor girders placed as far down in the corner of the anchorage as practicable. There are three lengths of eyebars between the cable shoes and the anchor girders, making a total number of eyebars in each anchorage of 732. The girders, which are of box construction, are about 40 feet long, and the end girders of each group are about 40 feet apart.

The mass of concrete directly over the anchor girders is designed with sufficient weight to insure that there will always be compression on an inclined surface in the plane of the bottom of the girders even with the maximum pull of the cables.

In general the anchorage above the foundations has been designed as mass concrete without reinforcing. At a few points, however, reinforcing has been provided. Reinforcing has been provided along the bottom at the back to allow the anchorage to bridge itself across from one foundation to another without danger of cracking. Vertical reinforcing at the back has been provided as an added precaution against tension during extreme amounts of cable pull. A reinforcing mat has been provided at the top of the front buttresses to strengthen the concrete against pressure from the inclined steel tower. Reinforcing has been provided in the longitudinal walls which may be subjected to tension due to upward pressure from the foundations beneath them. Other reinforcing is used only where local parts of the structure are subjected to beam action due to carrying the granite facing and walls, and as hook rods to bond together the anchorage as now constructed and the concrete and granite shell which is to be constructed later.

On each side of the anchorage at the back hollow towers of reinforced concrete construction are to be built which will house stairways and elevators leading from the ground up to the tracks and sidewalks of the bridge. These towers will be supported partly on the rest of the anchorage and partly on independent cylindrical foundations.

The end panel point of the suspended structure is carried by steel rockers supported on the inclined tower near its base, and the end of the first approach span is carried on seats at the back of the anchorage. The anchorage is thus subjected to the reactions from the side span stiffening truss and from the first approach

span, but, large as they are, these reactions are negligible compared with the weight of the anchorage and to the cable pull. Between the suspended structure and the approach the roadway, tracks and sidewalks of the bridge pass over the top of the anchorage and between the elevator towers, and are carried on steel work with columns resting mainly on the longitudinal walls.

THE FOUNDATIONS.

Returning now to the foundations, three stages may be noted in the development of their design. First, it was necessary to decide on the general type of foundation. Secondly, it was necessary to determine the exact size and location of the various parts, including the calculation of pressures. Finally, the detail construction of each part had to be designed.

Selection of the proper type of foundation depended on consideration of the soil and rock formation at the anchorage sites. Eight test borings had been made at the site of each anchorage, showing that in general there was a stratum of sand and gravel 60 feet deep in Philadelphia and 90 feet deep in Camden, overlying a rock formation of mica schist. From the samples of this rock taken at the top, from various phenomena connected with sinking the casing pipes and making the borings as well as from the cores of rock recovered, it was determined that the rock was very soft and disintegrated at the top, that its hardness increased gradually with the depth, that it became hard enough so cores could be recovered in depths of 15 feet in Philadelphia and 25 feet in Camden, and that it became a very hard rock at still greater depths. Additional information concerning this rock was obtained from the conditions met while sinking the caisson for the Camden Pier and from bearing pressure tests made in the working chamber at different elevations.

The type of construction selected for the foundations was that of sinking a number of reinforced concrete caissons through the sand and gravel and well into the soft rock, by means of excavating the material through dredging wells, building up the caissons as the sinking proceeded, and filling the dredging wells with concrete after the sinking was completed.

This type of foundation was selected in preference to two other types which were also studied. One scheme was that of excavating under the entire anchorage area to a depth of 20 or

30 feet and filling with concrete. This would have given a stable base with low bottom pressures suitable to resting on sand. However, the cost was estimated to be no less than that of the adopted design and it was considered inadvisable to have the foundation at a depth less than that of possible future structures in the neighborhood. Furthermore the test borings had shown that there existed on the Camden side a stratum of clay about 18 feet thick located 60 feet below the ground surface and 25 feet above the rock, and it was thought best to have the foundations go below this clay stratum.

The other alternative scheme was to have a large number of small caissons sunk by the pneumatic process down to very hard rock which would stand a high bearing pressure. In order to take care of the horizontal force the idea was to sink these shafts in an inclined position parallel to the average inclination of the resultant force, but even so the variation of this inclination would subject these shafts to eccentric or bending stresses necessitating their being fairly wide in the direction of the cable pull. Considering the necessary dimensions of such caissons and the relatively high cost of the pneumatic processes as compared with open dredging, it was estimated that they would cost considerable more than the adopted design.

The arrangement of caissons as finally designed consisted for each anchorage of two rectangular caissons under the front of the anchorage, each 40 feet wide and with lengths of 125 feet in Philadelphia and 140 feet in Camden, and of eight circular caissons or cylinders under the back of the anchorage each 20 feet in diameter. This arrangement gave large foundation areas at the front, long enough to take care of the horizontal force, together with a small area at the back, but one consistent with a well-distributed support. The depth of foundation tentatively determined from the boring data were to be at elevation –65 in Philadelphia and at elevation –95 in Camden, the greater length of the Camden caissons being necessitated by this greater depth. These bottom elevations were selected because a study of the boring data, together with conditions met in sinking the Camden Pier, seemed to indicate that at these depths rock would be encountered at all points sufficiently hard to properly support the foundation without being too hard at any point to permit of reasonably easy excavation. The actual sinking bore out in the main this

belief. The Philadelphia caissons were sunk to within a foot or two of the selected elevation, although the slope of the rock was such that in order to get the front end of the rectangular caissons to a satisfactory rock bearing the back end had to be sunk through a rock quite hard and requiring quite difficult excavating. It was found possible to sink the Camden caissons, however, about 8 feet deeper than the selected depth on account of the greater uniformity of material. The slight increase of pressure from that calculated due to the increased depth, was more than offset by the increase in hardness of the rock.

CALCULATION OF BOTTOM PRESSURES.

The method used in computing the bottom pressures is interesting because it was necessary to base it upon a study of the elastic behavior of both the foundations and the anchorage above them. The first consideration was that the horizontal component of the resultant force, or the horizontal shear, is distributed between the caisson not in proportion to their areas but in proportion to their elastic stiffness against horizontal deformation. This established that the rectangular caissons carried 95 per cent. of the total horizontal force. The distribution of the vertical component was first worked out on the assumption that plane sections at the top and bottom of the foundations remained planes, which is equivalent to assuming that the elastic shortening in the depth of the foundation varied uniformly from end to end of the anchorage. This assumption, although found later to be untenable, gave results sufficiently close to proportion tentatively the sizes of the foundation caissons.

For a plane section on the top to remain a plane the anchorage above the foundations would have to be absolutely stiff against elastic deflection. But it was found that bending stresses would occur in the longitudinal walls due to the upward pressure from the foundation under them. Although the walls would be amply strong enough to resist the bending, they would not be stiff enough to do this without allowing a deflection of the anchorage sufficient to invalidate the assumption of a plane section remaining a plane. In other words the walls, although reinforced to take the tension produced, would be stretched by the tension so as to let the back end of the anchorage tip back and the front end tip forward slight amounts, thereby giving a distribution of

bottom pressure different from that calculated with the above-mentioned assumption.

The final calculation of pressures was based on dividing the anchorage above the foundations into two parts, a front part and a back part, as shown in the accompanying diagram, and consider-

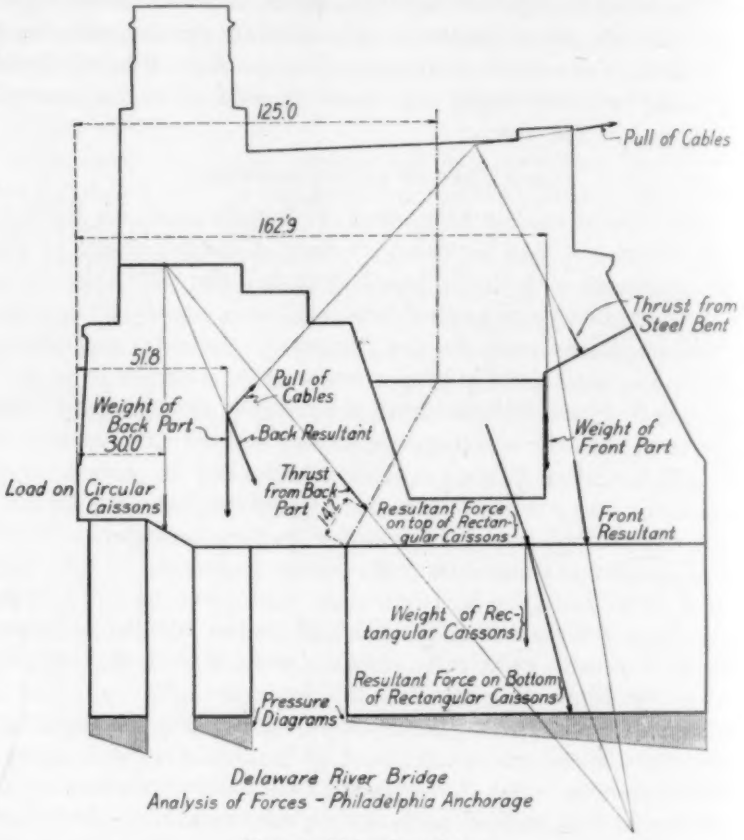


Diagram of forces in anchorage.

ing each part separately. The weight of the front part acting through its centre of gravity was combined with the thrust from the inclined steel tower to form a front resultant force coming down on the rectangular caissons. The weight of the back part acting through its centre of gravity was similarly combined with the pull on the anchor girders to form a back resultant force. This force was then resolved into two component forces, one

going down to the circular caissons, the other going forward to the rectangular caissons. These component forces, like the reactions of any structure, could not be found without first determining or assuming the position of each and the direction of one.

The line of division between the two parts of the anchorage was taken along an inclined plane from the upper back corner of the rectangular caissons to the top of the longitudinal walls, thus cutting through the whole anchorage at its narrowest point. The component of the back resultant force going to the forward caissons cuts this plane more or less at right angles, and at a point which, though not definitely known, can be determined within relatively narrow limits. This point must be far enough below the centre of gravity of the section to produce a reversal of stress or tension at the top of the wall of an amount corresponding to that which the preceding investigation had shown to exist. The position of this point was arbitrarily taken as that which would produce a tension at the top of half the average stress on the section. As practically all of the horizontal force is taken by the rectangular caissons, the component going to the cylinders was assumed to be vertical. It was assumed to act at a point two feet back of the mid-point between the two rows of cylinders. This point was selected as a result of a study of the elastic compression of the cylinders and the back end of the rectangular caissons.

Having thus established a line of action for one component and a point through which the other must pass, the amounts of the two components and the direction of the forward one were determined by the principles of statics. The back component was divided between the two rows of circular caissons according to its assumed eccentricity and, by adding the weights of the caissons themselves, the bottom pressures were found. The amount of horizontal force carried by these caissons is small and to simplify the calculations was neglected hitherto, but the bending pressures thereby produced were finally added to obtain the maximum pressures at the edges of the caissons.

The component of the back resultant going forward to the rectangular caissons was combined with front resultant to form the total force on these caissons. This, combined with the weight of the caissons, gave the resultant force on the bottom, from

which the bottom pressures under the rectangular caissons were found.

These calculations were made not only for the maximum pull of the cables which gave the maximum pressure under the rectangular caissons, but also for the minimum pull of the cables which gave the maximum pressure under the circular caissons. The minimum pull was taken as that due to the weight on the bridge of the steelwork only of the suspended structure, it being considered possible that the anchorage would be completed before more than this amount of load was on the bridge, but not before at least this amount had been erected. Pressures were also calculated for intermediate amounts of load on the bridge between these two extremes. In addition similar calculations were made for the anchorages constructed, as at present, to their first stage, both with no cable pull and with pulls due to the suspended structure being partially or even completely constructed, although this last condition is unlikely to occur because before that happens additional material will undoubtedly be added to the anchorages. The maximum pressures for the partially constructed anchorages were found to be less than those for the completed anchorages.

The pressures found as described were considered as gross pressures and were reduced by two factors to get the so-called net pressures. First, a part of the load was considered to be carried by friction on the sides of the caissons. This friction was assumed to amount to 400 pounds per square foot, the reduction it made in the bottom pressures being about three tons per square foot for the circular caissons, but only about one ton for the rectangular caissons. The other reduction consisted of subtracting the weight of the soil displaced including water. This amounted to about four tons per square foot in Philadelphia and six tons per square foot in Camden. The net pressures thus obtained represented the difference between the pressure under the caissons and the pressure in the adjacent material due to the overlying soil. The maximum net pressure for both rectangular and circular caissons was computed to be 22 tons per square foot for the extreme loading condition and 17 tons per square foot for usual operating conditions of the bridge.

There is an important factor making for the stability of the anchorages which was considered, but not counted on in the design. This is the passive resistance of the soil in front of the

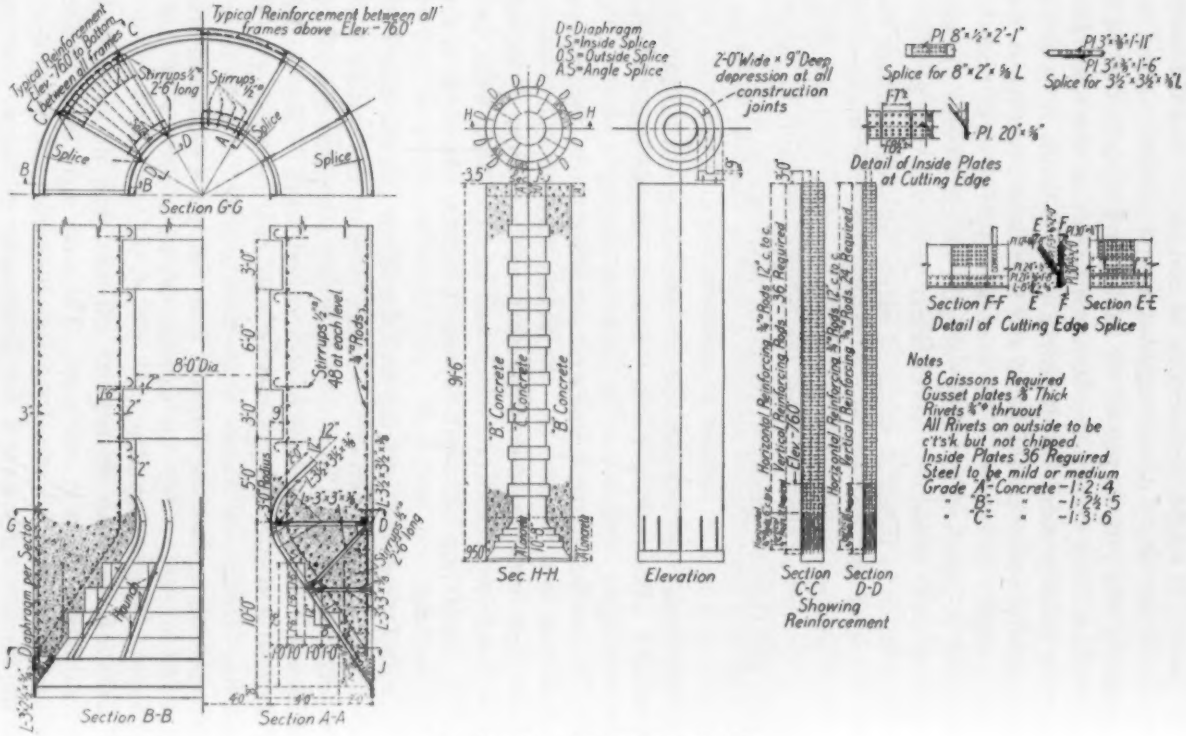
anchorage which would have to be overcome before serious sliding could occur. It might furthermore be considered that the earth pressure on the front of the caissons would partially offset the overturning effect of the pull of the cables, and by deflecting back the resultant force reduce the bottom pressure at the toe. But the active earth pressure on the front of the caissons is balanced by an equal pressure on the back, and it is doubtful whether the forward elastic deflection of the foundations of a small fraction of an inch is sufficient to bring into play an appreciable amount of passive earth pressure. Nevertheless this soil exists as a tremendous latent or potential factor of safety, although perhaps the chief value of this material is the vertical pressure it exerts on the rock adjacent to the caissons. This pressure, by preventing upward motion of the rock near the caisson, restrains its lateral motion and thereby greatly increases its bearing capacity.

DESIGN OF CAISSONS.

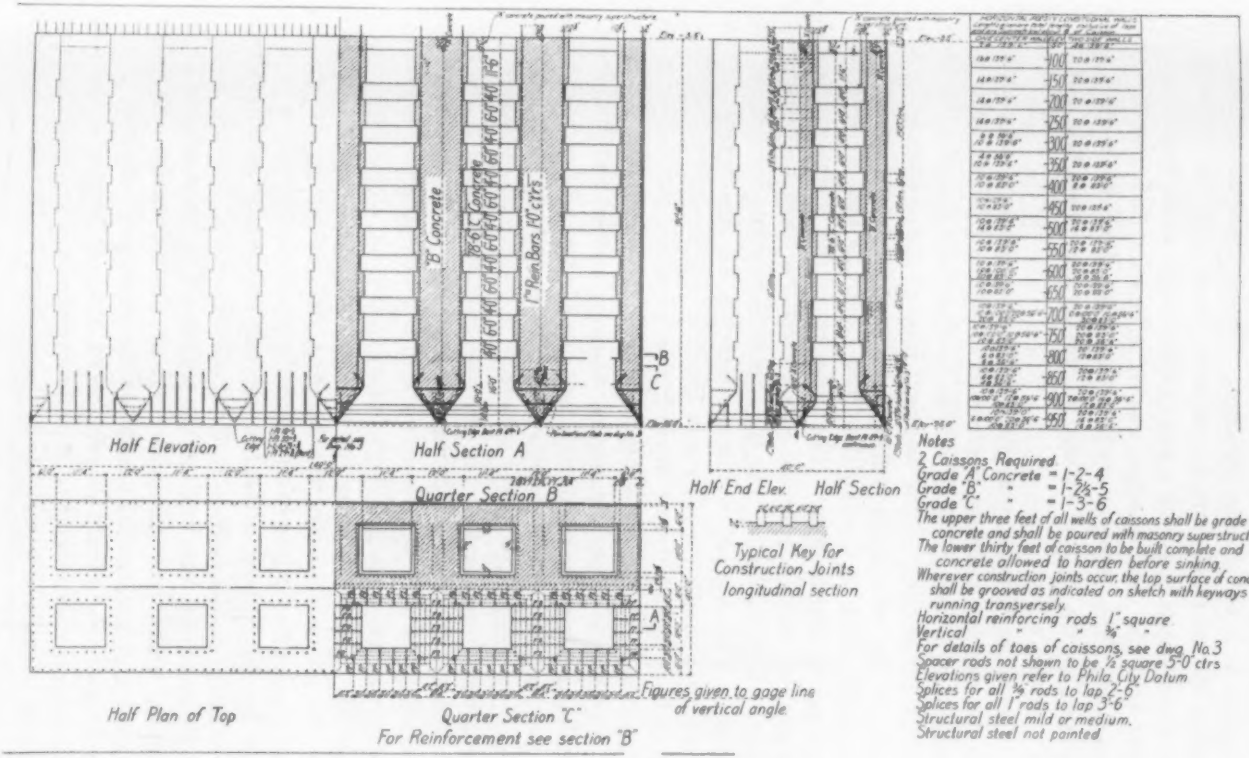
There remains to be described the detail design of the caissons for sinking. Each of the 20-foot circular caissons was designed with a dredging well 8 feet in diameter, leaving a shell 6 feet thick, reinforced at the inside and outside with ¾-inch-square vertical rods and hoops. On the inside face annular recesses 9 inches deep were provided at intervals for the purpose of having a good bond for the concrete which was later to fill the wells, and also for supporting bulkheads in case it became necessary to use compressed air.

At the bottom the dredging well flared out and the shell narrowed to a wedge-shaped cross-section, shod on the bottom with a circular steel cutting edge. The cutting edge was riveted to radial steel frames imbedded in the concrete shell. The bottom of the shell was also strengthened by additional reinforcing. On the inside between the frames, steps were provided in order to get direct bearing against the concrete later filling the well, and also to permit of supporting the caisson during construction independently of the cutting edge.

Each of the four rectangular caissons was designed with twelve dredging wells in two rows. The wells were made 10 feet wide and 11 feet 4 inches long, the exterior walls were 6 feet thick and the interior walls were 8 feet or more in thickness. All the walls were reinforced at both sides with one-inch-square horizontal


Typical Reinforcement between all frames above Elev. -76.0'
Typical Reinforcement Elev. -76.0 to Bottom between all Frames
Stirrups ⅝" 2'-6" long
Stirrups ½"
Splice
Section G-G
8'-0" Dia.
Stirrups ½" 48 at each level
⅝" Rods
Diaphragm per Sector
Rounds
Section B-B
Section A-A
D=Diaphragm
I.S=Inside Splice
O.S=Outside Splice
A.S=Angle Splice
2'-0" Wide × 9" Deep depression at all construction joints
18" Concrete
Sec. H-H.
Elevation
Horizontal Reinforcing ¾" Rods 12" c. to c. Required
Vertical Reinforcing Rods - 96 Required - Elev. -76.0
Horizontal Reinforcing ¾" Rods 12" c. to c. Required
Vertical Reinforcing Rods 96 Required
Section C-C Showing Reinforcement
Section D-D
Pl. 8" × ½" × 2'-1"
Splice for 8" × 2" × ⅜ L
Pl. 3½" × ⅜" × 1'-11"
Pl. 3½" × ⅜" × 1'-6"
Splice for 3½" × 3½" × ⅜ L
Pl. 20" × ⅜"
Detail of Inside Plates at Cutting Edge
Section F-F
Section E-E
Detail of Cutting Edge Splice
Notes
8 Caissons Required
Gusset plates ⅜" Thick
Rivets ¾" ø thruout
All Rivets on outside to be c't's'k but not chipped.
Inside Plates 36 Required
Steel to be mild or medium
Grade A - Concrete - 1:2:4
" B - " - 1:2½:5
" C - " - 1:3:6

Circular caisson for Camden anchorage.

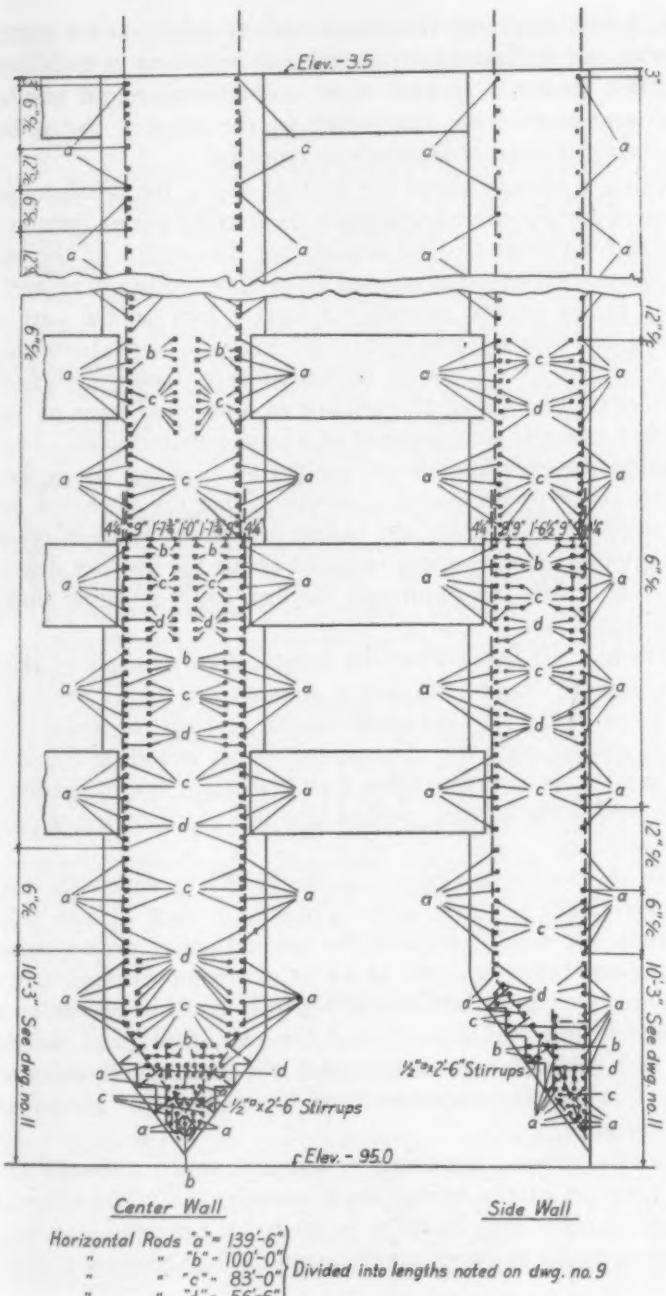

Half Elevation
Half Section A
Quarter Section B
Half End Elev.
Half Section
Typical Key for Construction Joints longitudinal section
Half Plan of Top
Quarter Section "C"
For Reinforcement see section "B"
Figures given to gage line of vertical angle
"B" Concrete
"C" Concrete
1" Reen. Bars 10" c's c's
Notes
2 Caissons Required
Grade "A" Concrete = 1-2-4
Grade "B" " = 1-2½-5
Grade "C" " = 1-3-6
The upper three feet of all wells of caissons shall be grade "A" concrete and shall be poured with masonry superstructure
The lower thirty feet of caisson to be built complete and concrete allowed to harden before sinking
Wherever construction joints occur the top surface of concrete shall be grooved as indicated on sketch with keyways running transversely
Horizontal reinforcing rods 1" square
Vertical " ¾" "
For details of toes of caissons, see dwg. No. 3
Spacer rods not shown to be ½ square 5'-0 ctrs
Elevations given refer to Phila. City Datum
Splices for all ¾" rods to lap 2'-6
Splices for all 1" rods to lap 3'-6
Structural steel mild or medium.
Structural steel not painted

Rectangular caisson for Camden anchorage.

rods and ¾-inch-square vertical rods, and 9-inch recesses were provided as in the circular caissons. The bottom construction was similar to that of the circular caissons except that the wells flared out more abruptly, giving a more obtuse angle at the bottom of the walls, and the cutting edge was of a heavier and stubbier construction. The interior walls were also shod with steel, but rounded on the bottom instead of having the projecting edge of the exterior walls.

The more slender, sharply pointed toe construction was used for the circular caissons, because their external surface was large compared to their weight, indicating that they would be held up mainly by friction. The heavier, blunter toe construction was used for the rectangular caissons because their friction area was relatively small, indicating that they would be held up mainly by pressure on the bottom. The strength of the toes was checked up against various assumed inward and outward wedging pressures, which indicated that they were amply but not excessively strong. The normal minimum amount of reinforcing in the upper part of the caissons was checked against unbalanced pressures both outward and inward, due to either the use of compressed air or to unwatering the wells, and was found sufficient.

In the case of the rectangular caissons, special additional reinforcing running longitudinally was provided to take care of bending or hogging stresses which might be set up during sinking. In order to make this most effective the general procedure for constructing and sinking the caissons was established at the time of making the design, and was incorporated in the specifications. The caissons were to be built up to a depth of 30 feet and allowed to harden twenty-eight days before dredging and sinking were started. The reinforcing for this 30-foot structure was designed on the assumption that the bending stresses set up by unequal bearing on the bottom during sinking would be equivalent to those due to the bottom pressures varying uniformly either from a maximum at the ends to nothing at the centre, or from nothing at the ends to a maximum at the centre. This gave tension at the bottom under one condition and at the top under the other. No attempt was made to calculate the position of the neutral axis or to apply the theory of reinforced concrete beams, because the uncertainties involved in the problem did not warrant such refinements. Instead the tension in the concrete walls was found for



Reinforcing in longitudinal walls of Camden caissons.

each 5-foot layer, at the centre and at other points along the caisson, and sufficient reinforcing was provided in each layer to take this tension. In each layer only the minimum number of rods were carried the full length of the caisson, the additional rods being stopped at intervals as required.

For the caisson above the 30-foot depth, the reinforcing was designed for the same assumption of distribution of bottom pressure and for even 10-foot depths, but the weight of the caisson was considered as partly carried by friction on the sides and ends to the extent of 200 pounds per square foot on the part under ground, and by a uniform hydrostatic pressure on the bottom of the walls. Only 10 feet of the particular depth being designed was considered to be above ground, but an additional layer of 10 feet of green concrete was assumed as a superimposed load. The construction was correspondingly limited by allowing not more than 20 feet above ground, with a provision that the lower 10 feet of this must be seven days old before additional sinking occurred. The amount of reinforcing required above the 30-foot depth was relatively small, the minimum number of rods being sufficient in the upper lays.

From levels taken after the construction of each of the first three 10-foot stages the initial stresses set up in the top and bottom of each wall were approximately calculated, and a contour of the cutting edge was determined which would give minimum stresses. This contour rather than a straight line was then used in the field as the normal position in which to maintain the caissons while sinking.

No restriction was placed on the height to which the circular caissons might be built above ground, in fact it was believed necessary for sinking to have the amount above ground equal to the amount below ground so as to overcome friction and that additional weight in the form of pig-iron would be necessary after the full length had been built. On the other hand no excess load was believed necessary to sink the rectangular caissons on account of their relatively small friction area compared to their weight.

Finally stresses occurring in the rectangular caissons during the operation of the bridge were investigated. The shear on a horizontal plane was found to be large but perfectly safe because accompanied by so much compression. The shear on a diagonal

plane at the front, however, is accompanied by little compression and would have been considered excessive were it not for the reinforcing in the caisson walls.

CONCLUSION.

The foregoing discussion has perhaps brought out the importance of the anchorages from the point of view of their design. From the point of view of the economy of suspension bridges anchorages are of vital importance. Suspension bridges are essentially economical structures as compared with other types for long span bridges. This economy, in terms of the cables, the towers and piers, and the suspended structure is very great indeed. If these elements only were considered, one might suspect from the result of comparative costs that some mistake had been made in the calculations. The mistake made would be that of neglecting to include the cost of the anchorages. Where nature has been kind enough to provide mountains at the two ends of the bridge, into which the cables can be anchored, the full economy of this type of structure can be realized. Otherwise the economy is somewhat reduced by having to construct massive artificial anchorages, costing from one-quarter to one-half as much as the bridge which stretches between them.

As the anchorages of this bridge play such an important part in both the cost and the stability of the whole structure, it is very fitting that they will take their place along with the cables and towers as conspicuous features of the bridge seen as a whole, and as monumental structures, when viewed close to, dominating their immediate surroundings. It is also very fitting that they will receive the handsome architectural treatment which their importance deserves, and one which so well brings out the function which they serve.

II. CONSTRUCTION.

BY

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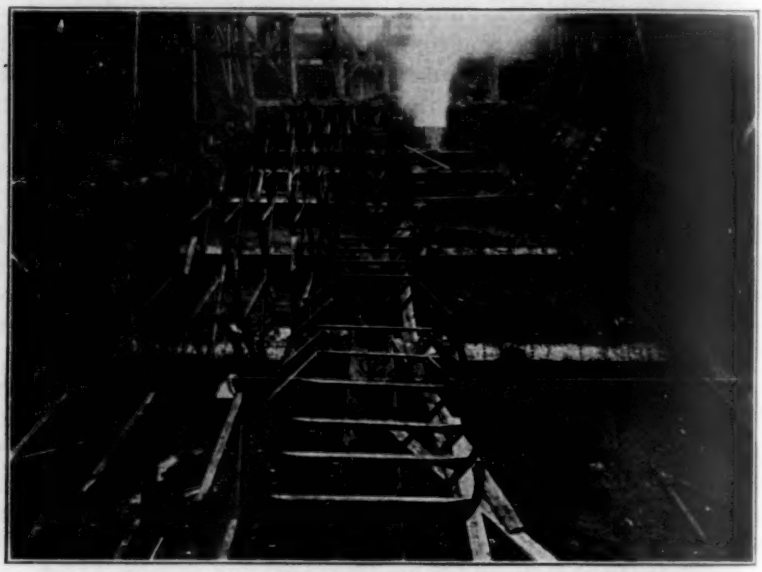
Senior Resident Engineer, Delaware River Bridge Joint Commission.

THE anchorages are the outstanding architectural feature of the bridge over the Delaware River between Philadelphia and Camden. Rising 175 feet above the street level, the massive granite structures mark the ends of the main bridge. It was decided to build these anchorages in two stages because neither

time nor funds were available to complete them and at the same time permit work to proceed on the towers and cables. The first section or stage of the anchorage construction was therefore made to consist of merely the foundations to bed-rock and the central mass of concrete with the necessary girders and eyebars to fasten the cables and resist, with a safe margin, the dead-weight of the cables and suspended steel structure during erection.

This program left sufficient funds available to proceed with the work on the main towers and cables while the first sections of



North caisson, Philadelphia anchorage, looking east. Steel cutting edges.

the anchorages were being constructed, and, with the additional funds now made available, the work of completing the anchorages may proceed in ample time to provide the additional mass to counterbalance the roadway pavement and traffic loads when the bridge is opened in 1926.

The first sections as now completed, both in Philadelphia and Camden, are almost identical above the ground-line. They each cover about three-quarters of an acre, being 218 feet long and 148 feet wide. In Philadelphia, this structure extends from Delaware Avenue to Front Street and extends down 63 feet to the bed-rock and required 28,000 cubic yards of concrete in the foun-

dations. In Camden, the bed-rock was reached at a depth of 104 feet under the rectangular caissons, while one of the circular caissons was carried down 111 feet. These foundations required 50,000 cubic yards of concrete. Above the foundations, each anchorage contains about 33,000 cubic yards.

Contracts for the completion of the anchorages will be let during the coming season. Under these contracts the present structure will be entirely faced with granite, additional concrete will be placed over the anchorage girders, and the foundations and

South caissons, Camden anchorage, looking west.

walls of the towers will be built. While the towers are an essential architectural element of the structure emphasizing the ends of the main bridge, they will also house the passenger elevators that will be provided to operate from the street level to the bridge deck, 100 feet above.

The design of the construction plant was very similar on each side of the river. It was arranged to take advantage of water transportation for bringing the concrete aggregate to the job and for the disposal of the material excavated from the foundations.

A trestle carrying both standard and narrow gauge tracks was built along each side of the site with a third branch through

the centre between the rectangular caissons. These tracks were connected by curves around the end so that locomotive cranes operated on the standard gauge tracks were able to reach all parts of the work. The narrow gauge tracks came together at the river end of the site where they were carried on a double track trestle leading to the concrete-mixing plants and muck-dumping boards, about 500 feet distant, at the river. The concrete and muck trains were hauled by gasoline locomotives.

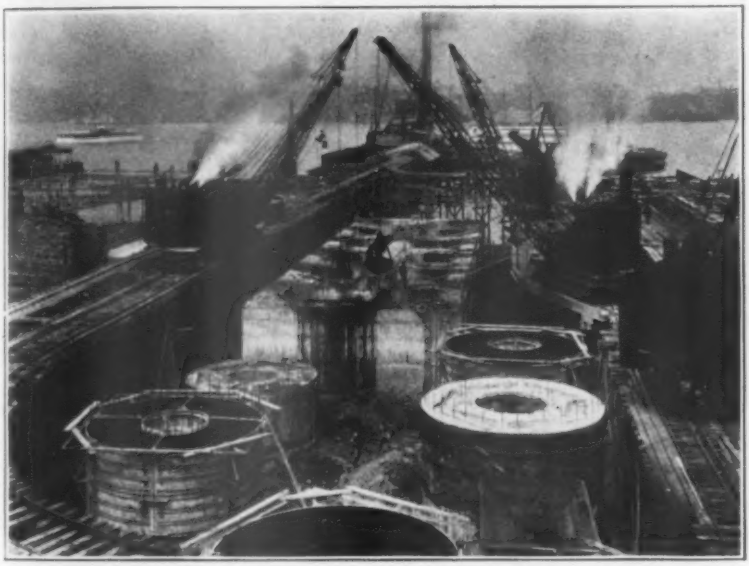
The concrete plants each consisted of two one-yard mixers with elevated bins and measuring hoppers. Two stiff leg derricks with clam-shell buckets were provided to fill the sand and gravel bins from barges delivered alongside. The cement was carried up to the level of the charging floor at the mixers on a belt conveyor from a storage shed of 1000 to 1500 barrels capacity.

Steel forms were used for both the rectangular and circular caissons, except for the inside forms at the bottom of the dredging wells where they flared out to the cutting edges. These were built of one-inch lumber bolted to the ribs which reinforced the cutting edges. On the rectangular caissons the steel forms provided for concreting a height of ten feet without shifting. The bottom edge was held by bolts embedded in the concrete of the previous lift and the top edge was stiffened and held in line by a light truss in the horizontal plane. Tie rods also extended across the walls to the forms for the dredging wells.

It was known that old bulkhead walls existed between Delaware Avenue and Water Street at the site of the Philadelphia anchorage. Test pits excavated before the buildings were demolished disclosed considerable timber cribbing of this nature. Some of it had evidently served as foundations for earlier buildings, but most of it was probably wharf construction along the water front of Colonial days. Since buried timbers of any considerable size would offer a serious obstacle to dredging operations, the specifications provided that the site should be prepared by stripping so much of the overlying fill as found necessary to remove all old foundations and buried timbers. During these operations, hewn oak timbers 24 inches square were removed and the parts of a barge or boat framed with wooden pins were discovered. The excavation was levelled off at elevation –9.0 and at this level the original gravel bed extended about two-thirds of the length of the caisson. The west curb of Delaware Avenue under the

bridge is at elevation zero on the Philadelphia City datum, which is used on the bridge. At the easterly or river end it was necessary to carry the excavation down to elevation −15.0 to remove all of the timber, and careful exploration with sounding rods was made for a depth of five feet below this level, after which the excavation was carefully backfilled with gravel from the west end of the lot.

Some pumping was necessary during these operations, but the water level did not respond to the tides in the river, 200 feet



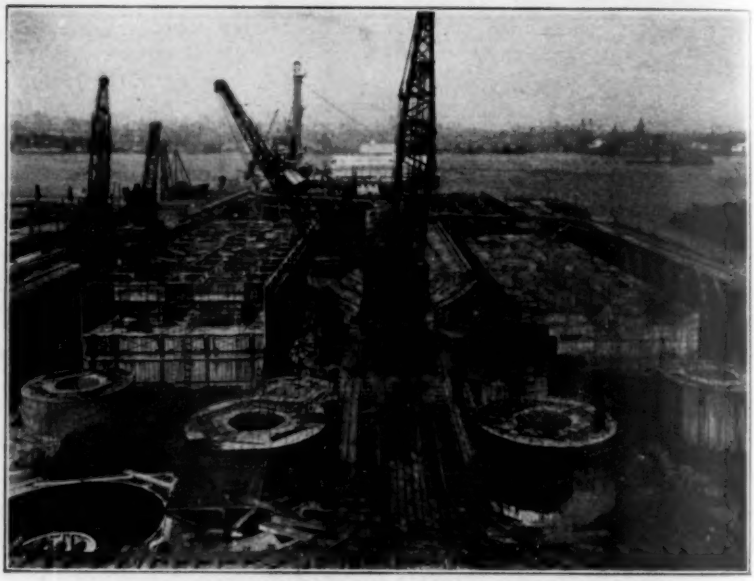
Camden anchorage south caissons, looking west.

distant, indicating that the Delaware Avenue fill was composed of impervious material and that the river-bed was silted over sufficiently to cut off flow through the gravel stratum. Drainage channels of broken rock and light wooden boxes leading to a pump sump located at one of the dredging wells were provided to take care of the ground water and keep the surface dry while the steel cutting edges were being assembled and riveted.

Conditions on the Camden side differed in that the site was located in an old slip between two wharves, making it necessary to drive a steel sheet pile cofferdam along the river end. This steel sheeting was heavily coated with Bitumastic and will be left as

a permanent bulkhead. There was considerable débris and mud to remove from the bottom of this slip, but no buried timbers, and an excellent gravel stratum was uncovered and levelled off to receive the cutting edges at elevation −12.0. On the surface thus prepared the steel cutting edges were assembled on light blocking, carefully levelled and the field splices were then riveted.

The problem of providing for stresses in the rectangular caissons during construction and before sinking was started, was recognized and taken care of in the design and specifications by



Camden anchorage, looking west. Steel forms may be seen on the left.

placing heavy reinforcement at the top and bottom of the first 30-foot section and requiring that this 30-foot section be allowed to harden twenty-eight days before any sinking operations were started. Each pouring of concrete was made in layers of at least three feet in depth and these layers were bonded by transverse keyways to assist the reinforcement in resisting horizontal shearing forces.

The construction of the first ten feet of the caisson required the greatest care because at this stage there was little beam depth developed to resist unequal settlement, although the structure weighed about 2½ tons per lineal foot of exterior cutting edge.

Blocking directly under the cutting edge was avoided for fear this blocking would be forced down by the weight of the caisson before it could be removed. Support was therefore obtained by lowering the assembled and riveted cutting edges into a prepared trench and packing or tamping the soil back as uniformly as possible. Additional support was obtained by placing three rows of 12-inch mud sills parallel with the cutting edges upon which were placed rows of posts bearing against the forms above.

The first four feet of concrete, which weighed about three-

Philadelphia anchorage, general view, looking southwest.

quarters of a ton per lineal foot, had to be supported largely by the direct bearing of the cutting edge in the trench. The interior cutting edges for the division walls between the dredging wells being V-shaped carried about twice as much weight per foot, but exposed twice the area for bearing so that the unit loads on the soil were the same. After the first ten feet of concrete were placed, sufficient beam action was developed to assist in resisting local deflections.

As the concrete loads increased the posts were wedged up where the levelling observations indicated necessary. Great care was used to adjust the supports so that the lower reinforcement and steel cutting edge were always in tension and never in com-

pression. When the first 30-foot sections had been completed ready for the twenty-eight days of hardening, the caissons had at no time been deflected more than two inches from a straight line through the ends. Settlements of various amounts up to 18 inches had taken place and the caissons were 8 inches out of level, but frequent levelling observations with readjustment of the supporting posts had successfully avoided objectionable deflections.

On one of the rectangular caissons in Camden this principle was carried a little too far and hair-cracks appeared in the concrete

Camden anchorage north caissons, looking west. Upper left circular caisson loaded with cast-iron sinking weight.

running from the bottom up several feet at a point about one-third of the length from the end. A readjustment of the blocking to give more support at the third points was made, which was quickly and entirely effective in reducing the deflections and closing the cracks. Calculations based on various assumptions as to the stresses set up by the observed deflection indicated that the reinforcement had not been seriously overstressed, and this point never gave any further trouble.

The profile of the cutting edges as observed and recorded at the end of the 28-day hardening period was taken to represent a

condition of minimum stress and future profiles taken as the sinking progress were referred to this minimum-stress line.

Sinking was started at the end of the 28-day hardening period by first carefully removing the posts and mud sills along the central portion of the caisson, next the supports were removed at the centre of the ends, and then at the corners. This was followed by undermining the cutting edges with hand shovels along the middle third of the caisson. After all timber had been removed from the dredging wells, the pump which had been in operation to discharge the water delivered to the sump by the underdrains was stopped and the ground water allowed to rise. Dredging by means of orange-peel buckets operated by locomotive trains was then started in the middle pockets. The muck was discharged into dump cars which were hauled over the trestle to the river, where they were emptied into barges for disposal. At first, the muck from the dredge buckets was dumped into a hopper from which the cars were loaded, but it was soon found that it was more satisfactory to load the cars directly from the dredge buckets and the muck hopper was dispensed with.

The behavior of the caissons while dredging varied widely with the class of material being penetrated by the cutting edges. In sand and gravel, the caissons usually followed the dredging quite gradually, the motion seldom being perceptible to the eye, although a settlement of several inches might be observed within an interval of a few minutes. While dredging in clay or disintegrated rock the caissons would frequently hold up until the excavation was ten feet or more below the cutting edge when, without warning, a sudden drop would occur and the cutting edge would plow the penetrated material to the centre of each dredging well where it could be more readily removed by the dredge bucket. It was quite an uncanny sensation to be on the caisson when one of these drops occurred. The sudden motion of so large a mass rather upset preconceived ideas of stability. There was no jolt or jar because the friction and cushioning effect of the penetrated material brought the caisson to rest gradually. There were drops of as much as four feet for the rectangular caissons. On the circular caissons this was frequently exceeded and one drop of nine feet forced the water in the dredging well out over the top.

When the caissons hung up until the excavation was more than eight feet below the cutting edge, the dredging became very

tedious and expensive because the material supporting the caisson was in a berm along the cutting edge under the walls of the caisson and not under the dredging well where the teeth of the open dredge bucket could reach it. This objection could be readily overcome in future designs by making the walls of the dredging wells thinner so that the dredge teeth would reach out to the cutting edge, but this would be done at the expense of strength and weight. Additional sinking weight would probably be required which would offset the saving in dredging expense. The tower foun-

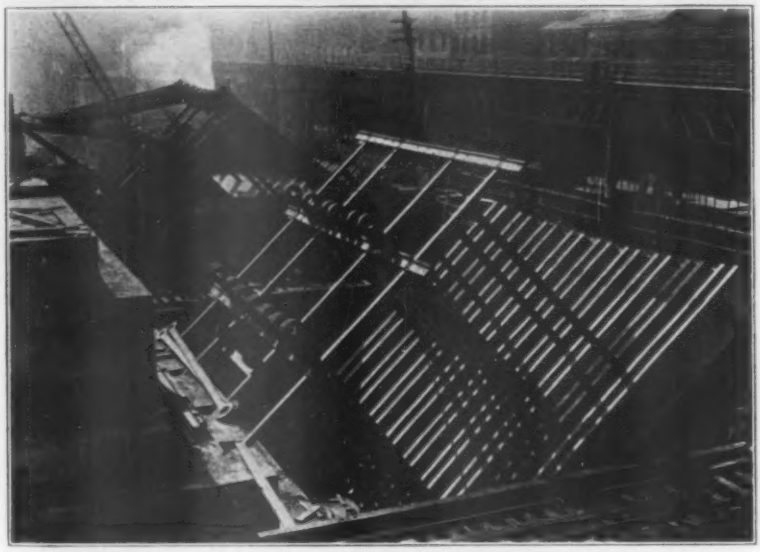
Philadelphia anchorage, south rectangular caisson. Bed-rock in well No. 2.

dations will have circular caissons with a thinner wall, so that the sinking of these caissons will give further information on this point.

For this reason it was desirable to keep the caissons as heavy as possible so that they would force their way down and plow the material to the centre of the well within reach of the dredge bucket. After the first 30-foot section had been sunk so that the top was near the ground surface, an additional height of 20 feet of concrete was placed, and after seven days of hardening the dredging was resumed.

The south rectangular caisson in Philadelphia was started first

and hence much of the pioneering as to details of method were developed on this caisson. When this cutting edge had reached elevation −57.0 progress became very slow and various expedients were tried. Jetting with a three-inch pipe, carrying 125 pounds pressure on a 1½-inch nozzle, proved ineffective. Chiselling or picking with a 30-foot rail pointed with a steam-shovel tooth produced no results. Pumping out a portion of the water in the dredging wells to reduce the buoyancy of the caisson and give additional effective weight caused some sinkage, but the soundings



Philadelphia anchorage, looking south. Anchorage girders and eyebars.

showed that the water drawn in under the cutting edge was dragging in material from outside the area of the caisson. This was also shown by the settlement of the ground around the caisson at the east end and this settlement threatened the stability of the trestles on which the cranes were operated.

While these operations were under way one of the circular caissons had been sunk to considerable depth, and although loaded with 200 tons of pig-iron, sinkage had become very slow. The dredge bucket was bringing up very small loads, which consisted principally of soft micaceous schist that could readily be crumbled in the hand. An examination in a diving suit showed that the

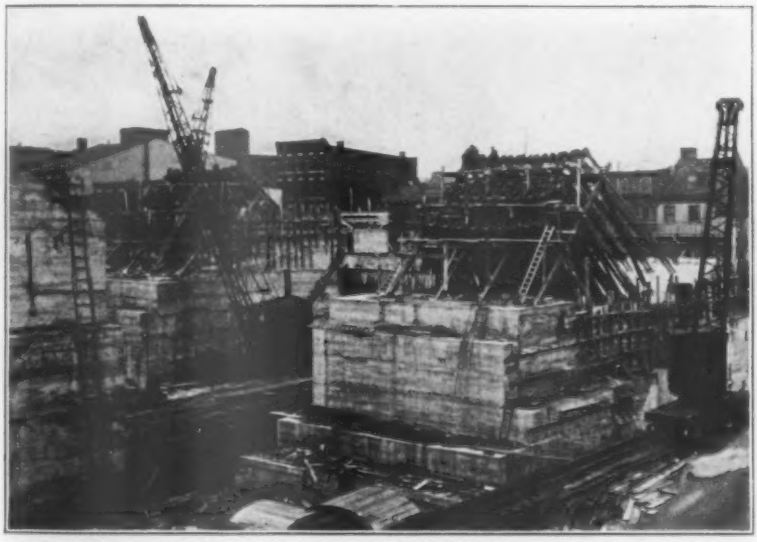
cutting edge rested on this soft micaceous schist all the way around and that the dredge bucket had dug a hole about five feet deep in the centre under the dredging well, the caisson being too light to penetrate farther and plow the material within reach of the bucket. The ground water was evidently partially cut off at the cutting edge, as indicated by the lowering of the water in the caisson by the dredging operations. It was decided to attempt to pump out the caisson to get additional effective weight by removing the buoyancy and with the possibility of reaching the cutting edge,

Camden anchorage, north eyebars, looking northeast.

so that the supporting berm around the circumference could be excavated with hand tools. The water was successfully pumped down to the cutting edge at the first attempt, and although the sinking of this caisson was not continued at that time, this method was later used on all of the caissons.

With the information obtained on the circular caisson, it seemed feasible to pump out the south rectangular caisson. Careful examination by divers showed that the west end was resting on the soft rock while the east end towards the river was in sand, gravel and clay, the rock sloping down six to eight feet lower. The four wells at the east end were backfilled to a depth of about

ten feet with gravel and clay to restrain the material outside the caisson from dragging in under the cutting edge while pumping out the water. The pumping operations were started with centrifugal pumps, but after several days' work, a change was made to reciprocating mine pumps, which proved more effective and could be more readily lowered. After more than two weeks of pumping the bottom was reached and immediate steps were taken to remove the soft rock where it was supporting the caisson, so that the sinkage accomplished would assist in cutting off the

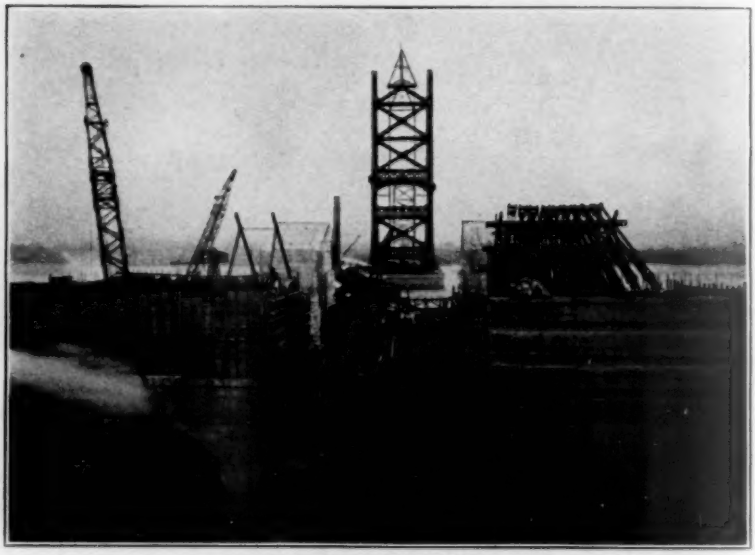


Philadelphia anchorage, looking southwest.

water. At times the quantity of water pumped amounted to eight or nine hundred gallons per minute. This large volume of clear cold water discharged from the pumps looked very inviting during the summer weather and was being carried home for drinking purposes by the residents in the neighborhood. After samples had been sent to the laboratory, notices were posted giving warning that the analysis had shown the water to be highly polluted and dangerous to health.

As the excavation progressed, the rock encountered increased in hardness very gradually. There was no sharp line between material that could be removed by a pick or jack hammer and that which required drilling and blasting. During the last few feet

of sinking, when the cutting edge was 60 to 63 feet below the curb level, the caisson was supported on timber posts to prevent it from following down as the supporting material was excavated and thus doing local damage to the cutting edge before all of the rock could be blasted out to the full area of the caisson. These precautions were taken after some bending and breaking of the cutting edge had occurred. At this time it was possible to pass from one chamber to another under the division walls between the dredging wells. When the rock had

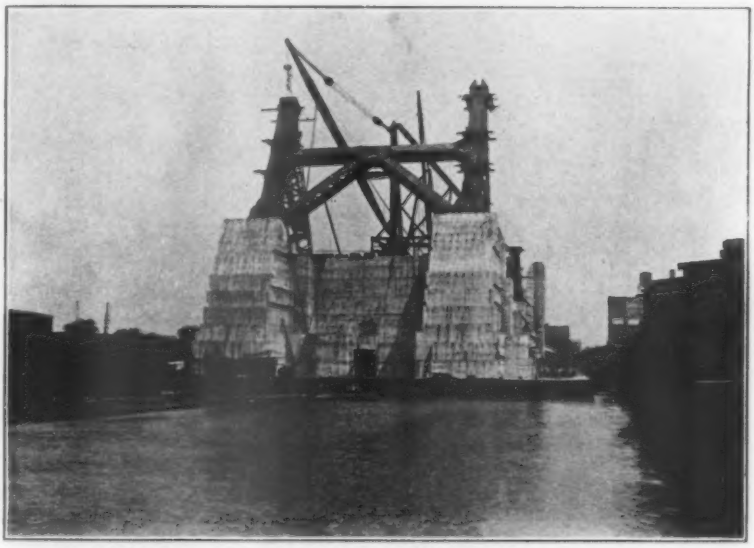


Camden anchorage, looking west.

been carefully excavated to clear the entire cutting edge the supporting posts were shot out and the caisson lowered to its final position. The rock over the entire area was then thoroughly cleaned ready to receive the concrete which formed the foundation bed. Depressions of several feet were blasted in the rock to form a very rough and rugged surface to resist the horizontal component of the pressures on the foundation.

Practically all of the water coming into the caisson entered under the cutting edge and not in springs through the bed-rock. This water was led by gravel drains to the pumps located in two centre wells. Concrete was thus placed in the dry and thoroughly

packed under the cutting edge. It was carried up in this manner to a depth of ten feet, which entirely filled the enlarged chamber at the bottom of each dredging well. The pumps in the two central wells were then stopped and the water allowed to rise. These two wells were then concreted under water to a depth of ten feet through a tremie. After this concrete had hardened the water was pumped out and all of the wells were then concreted to the top of the caisson, which now formed a solid block of concrete 40 feet by 125 feet from the bed-rock to the surface of the ground.

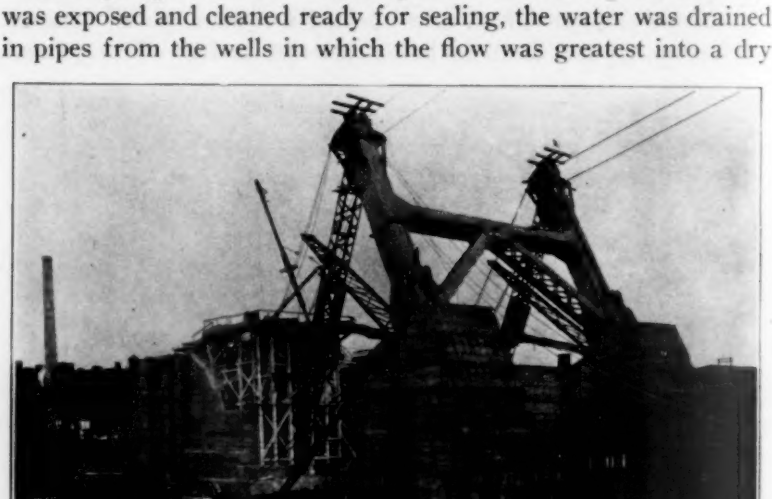


Camden anchorage, looking east. Cable bent nearly completed.

The Philadelphia anchorage caissons were sealed at an average elevation –63. The main pier, 700 feet to the east, reached the bed-rock at elevation –65. On the Camden side the rock under the main pier was found at elevation –83, while the caissons for the anchorage pier, 700 feet farther east, were sunk to elevation –104.

The Camden caissons were handled in a very similar manner, but with the advantage of the experience gained and somewhat more favorable soil conditions. While the bed-rock was much deeper, 104 feet instead of 63 feet, it was overlaid with several feet of soft disintegrated rock into which the cutting edges could be forced to cut off the flow of water before pumping was started.

This made it possible to bail the water out with large buckets made from old three-foot diameter shafting and swung from the locomotive cranes. The bailing avoided the slow, tedious process of staging down the pumps as the water was lowered, but when the caisson was unwatered two pumps were installed to take care of the seepage water which amounted to less than one-fourth the amount pumped on the Philadelphia side. After the bed-rock was exposed and cleaned ready for sealing, the water was drained in pipes from the wells in which the flow was greatest into a dry



Philadelphia anchorage, looking northwest from Delaware Avenue.

well, where a pump was installed. This drain pipe was then brought up ten feet or more above the cutting edge, and after the ten-foot concrete seal was placed, the pipe was capped and the well sealed in the dry without the use of a tremie. No difficulty was experienced in holding the caissons on the desired locations while sinking. The cutting edges were placed in accurate position at the time they were assembled and the dredging operations in the various wells were so directed as to keep the caissons approximately level.

Work on the circular caissons was carried on at the same time as that on the rectangular caissons. They were 20 feet in diameter, with an eight-foot dredging well, and had a V-shaped cutting

edge two inches thick built up of half-inch steel plates. These cutting edges were assembled directly on wood-blocking which was left in place when sinking was started. By placing the blocking radially with about two-thirds of its length to the outside, the timber was forced to the outside and removed before it was carried down with the caisson.

The circular caissons weighed about 600 pounds per square foot of surface exposed to friction. Deducting for buoyancy left less than 360 pounds per square foot effective weight to overcome

General view of bridge, looking northwest from Delaware Avenue, Camden.

the friction when the top of the caisson had been sunk to the surface of the ground. To make the dredging most effective, it was desirable to keep the caissons built up ten to twenty feet above the ground surface as the sinking proceeded. Additional weight in the form of pig-iron and cast-iron blocks was also used in overcoming the friction. Such weight was not necessary on the rectangular caissons. When the cutting edge penetrated the disintegrated mica schist the water was bailed or pumped out and the sinking proceeded in the dry with hand tools. After several feet of penetration in the disintegrated rock these holes were comparatively dry by the time the solid rock was reached. In sealing, the concrete was placed rapidly so that the pressure of the concrete

overcame the hydrostatic head before an objectionable amount of water accumulated.

After the foundations had been completed, the building of the concrete mass above the ground line involved no particularly new features. The upper three feet of the dredging wells were poured with the superstructure to provide ample shear keys against the horizontal forces. All horizontal joints and vertical joints in a longitudinal plane were carefully keyed. The structure is, in general, all mass concrete without reinforcement except through a few critical sections and under the bearings of the anchorage cable bents.

The exterior surfaces, which are to be faced with granite under the next anchorage contract, are provided with projecting bonding rods of one-inch-square hooked reinforcing steel, spaced about one to each twenty square feet. These hooked rods will be imbedded in the concrete backing of the granite face and with the headers of the granite masonry should provide ample bond.

Concreting operations were carried on during the past two winters with few interruptions from cold weather. By heating the aggregate and mixing water to a temperature of 60° to 75° F., it was found that the mass would maintain a temperature of 40° to 50° for several days after pouring when the air temperature was between 15° and 25°. It was usually found that the temperature would rise 4° or 5° the first twenty-four hours after mixing, due to the chemical action of the setting of the cement.

The work of setting and regulating the anchorage girders and eyebar chains involved a great deal of painstaking and tedious instrument work. The pit to receive the girders was a cylindrical surface with the axis of the cylinder at an angle of 43½° from the horizontal. The backs of the girders lie on this cylindrical surface with the centre plane of each pair of girders radial. The eyebar chains were supported on steel falsework and carefully aligned before they were embedded in concrete. A clearance of 1/32 of an inch was allowed between the pins and the pin-holes, but particular care was taken to wedge the bars tight against the pins in the direction of the pull of the cables before the concrete was placed around them. A dense rich mixture of concrete with nominal proportion of one part cement, one and seven-tenths parts sand and three and four-tenths parts gravel was used in the anchor pit over the girders and first links of bars. This mixture resulted

from adding one bag of cement to a six-bag batch of nominal 1:2:4 concrete. The bottom of the anchorage pit, or lowest corner of the anchorage girders, is about level with the ground surface, so there will be little ground moisture for this concrete to resist.

The main cables approach the anchorage at an angle of 8° from the horizontal and are deflected over the anchorage cable bents to an inclination of 45°, where they attach to the eyebar chains which are pinned into the girders at the bottom of the anchorage mass. The main section of the columns of the anchorage cable bents is seven feet by eight feet in cross-section, with interior webs making them cellular, like the columns of the main towers. The lower section is flared out by stiffening webs where it bears against the steel castings which distribute the pressure on the concrete. The columns are braced midway of their height by a horizontal strut.

The thrust from these inclined bents is carried down through the concrete pedestals at the forward or river end of the anchorage to the rectangular caisson foundations and will produce the maximum foundation pressure when the bridge is completed and in service.

At the top of these bents the cables will rest in saddle castings, which are machined to a 14½-foot radius where the cable bends down into the anchorage. This curved surface is also grooved longitudinally to conform to the shape of each of the strands of the cable that bear directly against the saddle.

Temporary steel struts are provided to support the bent in its inclined position during erection. After the cables are in place these supporting struts will be removed.

The Meaning of the Word "Alum" is the title of a monograph of thirty pages by AUSTIN M. PATTERSON, copyright 1924. Alum and its equivalents in modern European languages are derived from the Latin "alumen." While the ancients applied the Latin alumen or the Greek stypteria to a number of astringent substances, it is a matter of dispute whether they were acquainted with any of the crystalline double sulphates now designated alums. The mediæval alchemists knew crystallized alum, either or both potassium aluminum sulphate and ammonium aluminum sulphate. Alum is mentioned in English during the fourteenth century, for instance by Chaucer.

Both potash alum and ammonium alum are recognized by the Pharmacopœia of the United States. Soda alum (sodium aluminum sulphate) is far more soluble, less readily crystallized, and, therefore, more difficult to obtain free from impurities. The existence of this alum has been fully established. It has become an article of commerce since 1867; and several patents have been granted for its manufacture. Dehydrated soda alum, designated S. A. S. (the initial letters of sodium aluminum sulphate), has been the acid ingredient in most alum baking powders since 1900.

The word alum is used in three senses: (1) Pharmacopœial alum, especially potash alum; (2) the crystallographic family of the alums; (3) aluminum sulphate in any form, alone or as a double salt. The common meaning of alum is summarized in the following paragraph:

"The term 'alum' as first used in English probably denoted no more than 'an astringent mineral salt.' As knowledge grew the connotation of the term presumably narrowed to that of 'a whitish, astringent mineral salt.' This last expression represents pretty fairly the notion which the average person of the present day has of 'alum' taken in connection with whatever he may know about its uses and effects. If it has the color and taste which he associates with alum and if he is informed that it contains the same active ingredient, reacts in the same way chemically and has the same physiological effects, he will be likely to insist that it is 'alum' to all practical intents and purposes, regardless of technical refinements." J. S. H.

Microscopic Detection of Fortified Milk.—DAVID WILBUR HORN (*Amer. Jour. Pharm.*, 1924, **96**, 365) has devised the following procedure for the detection of condensed milk in fortified milk, *i.e.*, the adulteration of fresh milk with condensed milk. Definite results were obtained when the ratio of condensed milk to fresh milk in the fortified product was 1 volume to 60 volumes. The milk is subjected to centrifugation in a lactocrit for ten minutes at a velocity of 2000 or 2100 revolutions per minute. A smear is made of the sediment, permitted to dry, and simultaneously fixed and stained by treatment with a solution of methylene blue in wood alcohol. The stained smear is washed, permitted to dry, and subjected to microscopic examination. The sediment from fortified milk contains numerous foreign bodies which do not occur in the sediment of normal milk, either raw or pasteurized. "In their appearance, these foreign bodies are suggestive of minute starch grains, and are readily distinguished from minute fat globules by their irregular forms and the fact that they take some of the stain whereas the fat globules remain colorless. Sometimes these foreign bodies give the visual impression of collapsed spheres, after the manner of red blood-cells, but they are much smaller." At times, centrifugation produces visible deposits of white solids from such fortified milks. J. S. H.

THE INFLUENCE OF STIRRING ON THE RATE AND COURSE OF DEVELOPMENT.*

BY

S. E. SHEPPARD and FELIX A. ELLIOTT.

Research Laboratory, Eastman Kodak Company.

PART II.

In a previous communication [1] we have described an apparatus for investigation of the effect of rate of flow on the velocity of photographic development. The velocity of flow in these experiments did not exceed 3 cm. per second, corresponding to about 400 r.p.m. of the stirring. It was stated that this velocity is still considerably below that used in continuous development of motion picture film. Before passing to conditions reproducing those in continuous processing, it appeared desirable to extend the results obtainable with the previously described apparatus and method; particularly because in some cases a tendency was observed for the velocity of development to increase at the highest speed then attainable. The apparatus was therefore modified to permit higher stirring velocities. The results of the experiments at higher velocities with four different developers are shown in the accompanying curves. Temperature was maintained constant at 20° C. ± 0.1°. The general composition of the developer was as follows:

Reducing Agent.	M/20
Na_2CO_3	50 gm. } per 1000 c.c.
Na_2SO_3	50 gm. }

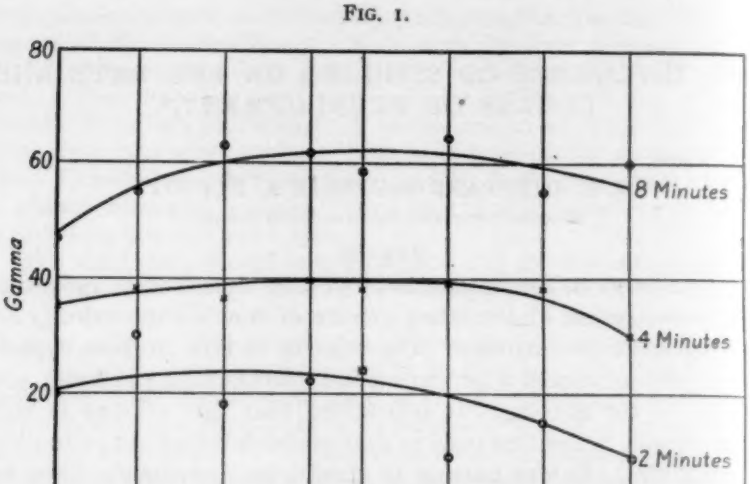
Eastman portrait film was used in all the experiments.

The gamma revolution curves for hydroquinone show some tendency to a maximum, but not pronounced. With the other three developers investigated, the velocity of development remains practically constant up to about 120 r.p.m. and then rises fairly rapidly to a well-pronounced maximum in the neighborhood of 720 r.p.m. The reason for the observed increase in developer efficiency at the higher speeds is not apparent, nor the subsequent

* Communicated by Dr. S. E. Sheppard, Acting Director. Published as communication No. 208 from the Research Laboratory of the Eastman Kodak Company.

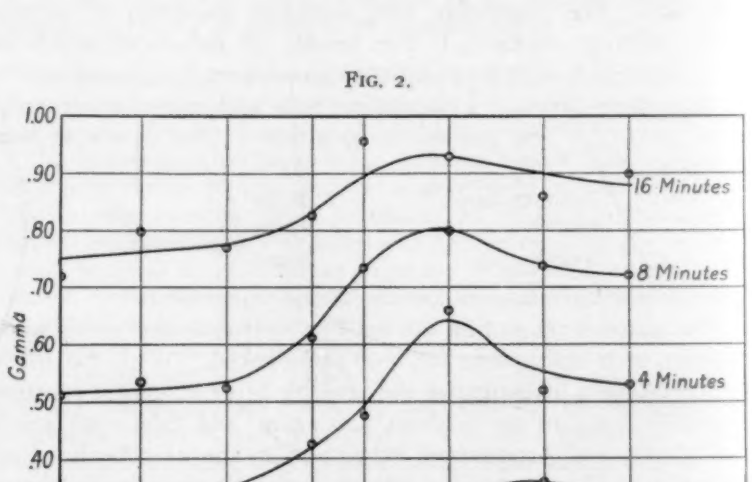
[1] Jour. Frank. Inst., June, 1923, p. 211.

FIG. 1.



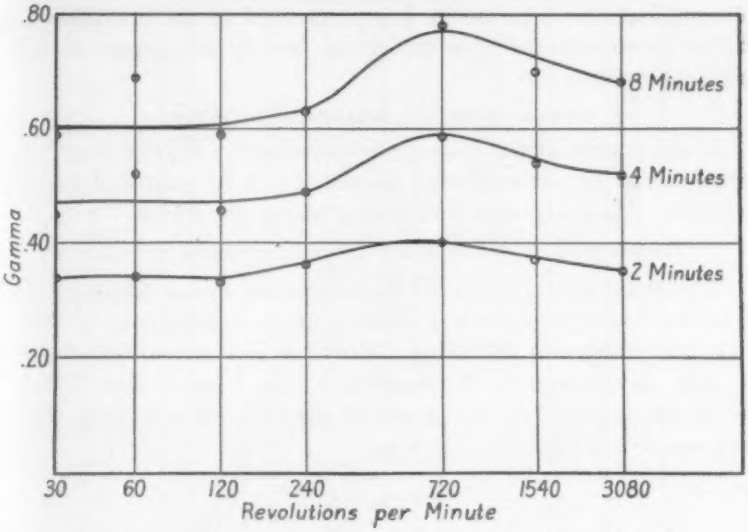
The effect of different speeds of rotation on gamma using hydroquinone developer.

FIG. 2.



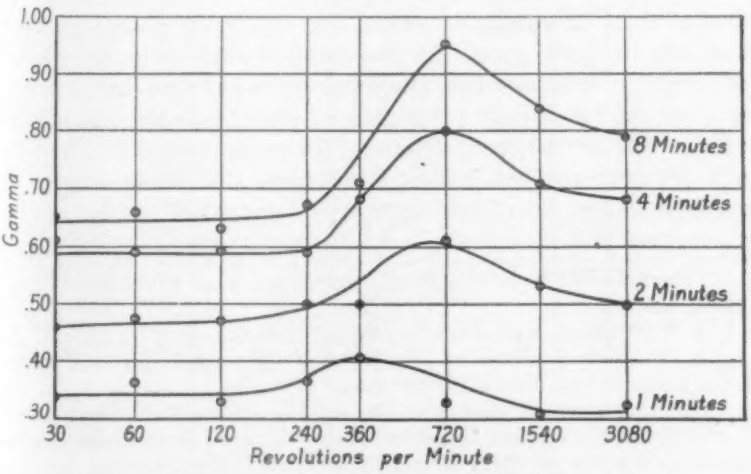
The effect of different speeds of rotation on gamma using a pyrogallol developer.

FIG. 3.



The effect of different speeds of rotation on gamma using p-aminophenol developer.

FIG. 4.



The effect of different speeds of rotation on gamma using Elon developer.

falling off and return to a value approaching that at low speeds. The production of turbulent flow, increased aerial oxidation and similar factors are being investigated, but do not appear to offer sufficient explanation.

CHARACTERISTIC DEVELOPMENT CURVES.

If the curves of the four given developers (Figs. 5 to 16) are compared at the same stirring speeds, it will be seen that there is a definite change in type on passing along the series.

Hydroquinone ⟶ Pyrogallol ⟶ p-Aminophenol ⟶ Elon

The density-time curve for hydroquinone shows a well-marked induction; this becomes less evident in pyrogallol, and is absent with p-aminophenol and Elon. This corresponds to the division of such developers by A. Watkins[2] into "low" and "high" factor developers. This change in the type of the curve shows that simple functions of the type

(*a*) $$1/t \log \frac{D\infty}{D\infty - D} = K$$

(*b*) $$1/\log t \log \frac{D\infty}{D\infty - D} = K$$

as developed by Sheppard,[3] Nietz and others,[4] can only be regarded as giving a very approximate description of the course of development. The fact that such formulas find considerable use and value in sensitometric practice may be partly accorded to the general use of blended developers, Elon-hydroquinone, Elon-pyrogallol, or of pyrogallol alone, for which the fitting by such functions is fairly good. In the blended developers, at normal temperatures, compensation is effected by which the initial inductions and later deduction (retardation) effects balance out to some extent. The existence of definite differences in type of function with different reducers makes it desirable that these factors be investigated and determined separately[5] and work on this is now in progress.

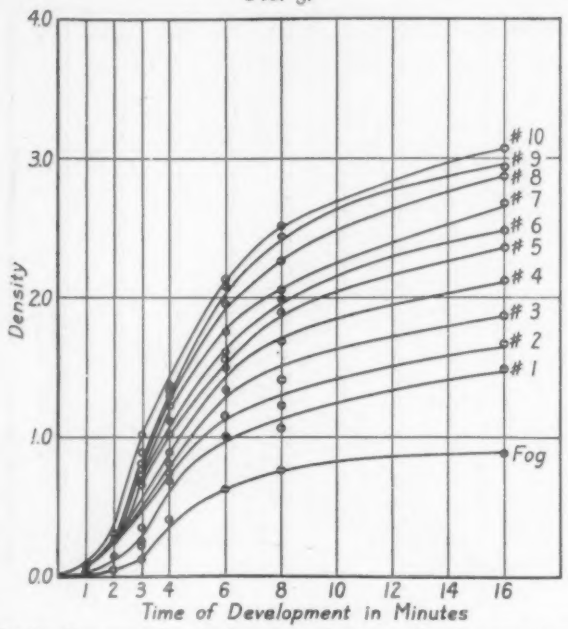
[2] "Photography: Its Principles and Application," p. 92 (Constable and Co., London, 1911).

[3] S. E. Sheppard, *Proc. Roy. Soc.*, **74**, 457 (1904).

[4] A. H. Nietz, "Theory of Development," Monograph No. 2, Eastman Kodak Company and Van Nostrand (1922).

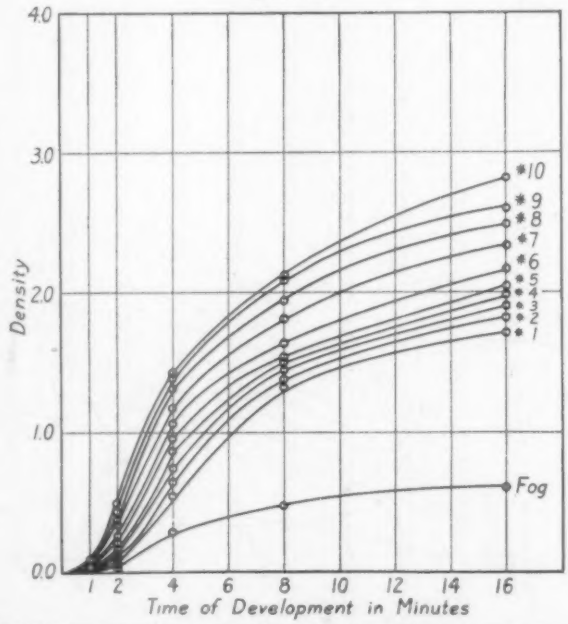
[5] *Cf.* S. E. Sheppard, *Phot. Jour.*, **43**, 136 (1919); also S. E. Sheppard and F. A. Elliott, "Knowns and Unknowns in the Theory of Development," in the Physical Chemistry of the Photographic Process, *Trans. Faraday Soc.*, 19, 355, Pt. 2.

FIG. 5.



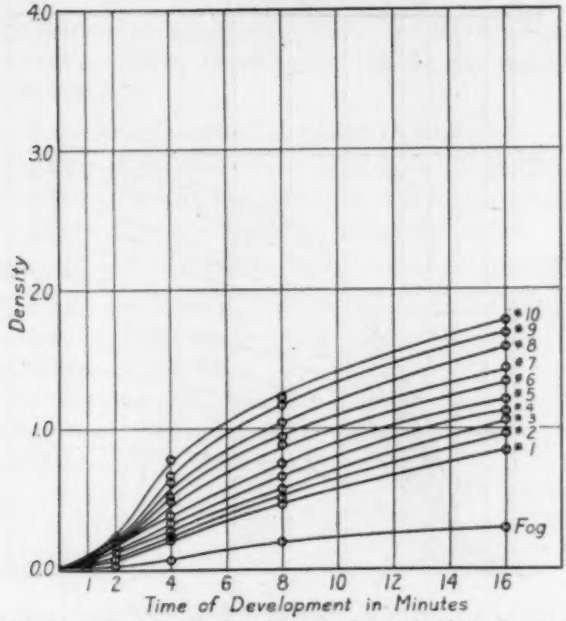
Density-time curves for a hydroquinone developer stirred at 720 r. p. m.

FIG. 6.



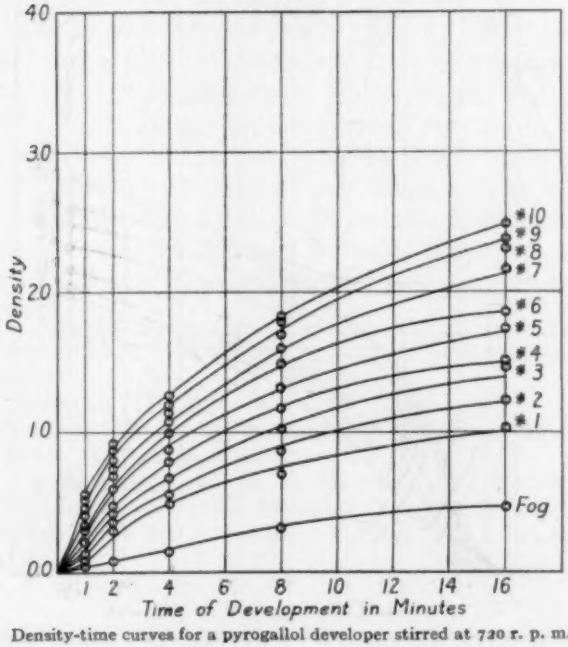
Density-time curves for a hydroquinone developer stirred at 1540 r. p. m.

FIG. 7.



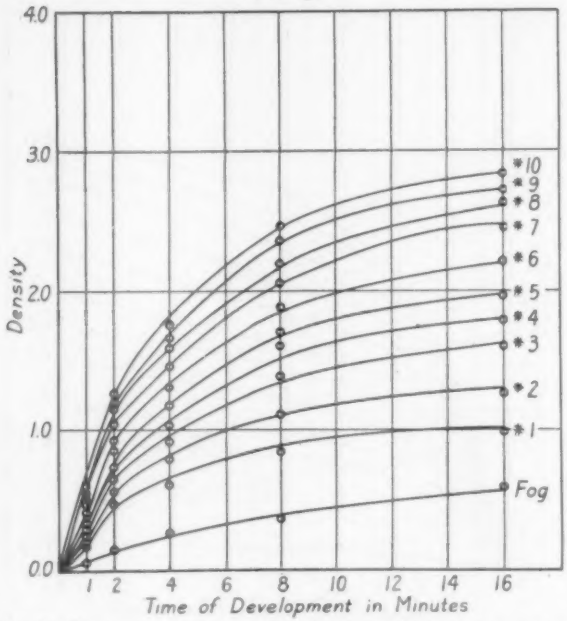
Density-time curves for a hydroquinone developer stirred at 3080 r. p. m.

FIG. 8.



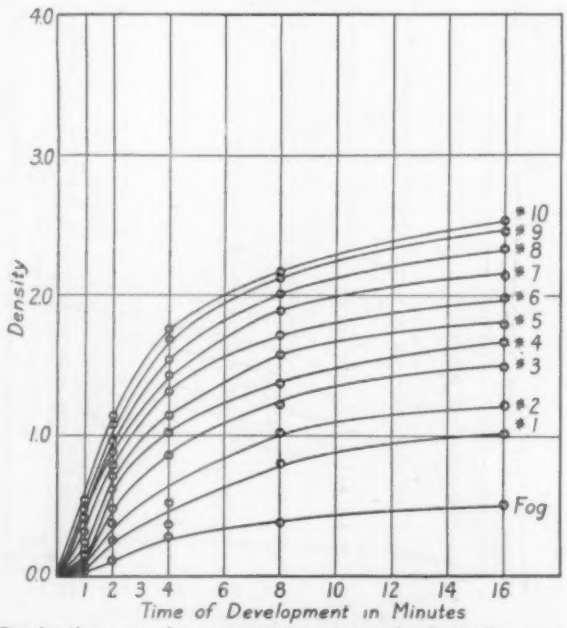
Density-time curves for a pyrogallol developer stirred at 720 r. p. m.

FIG. 9.



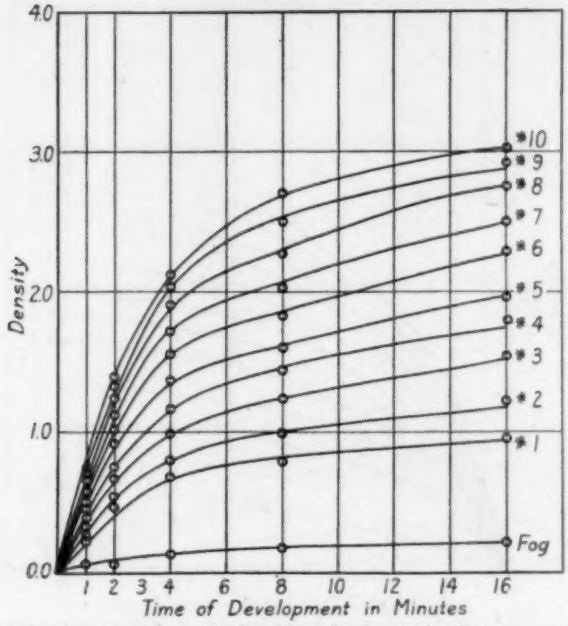
Density-time curves for a pyrogallol developer stirred at 1540 r. p. m.

FIG. 10.



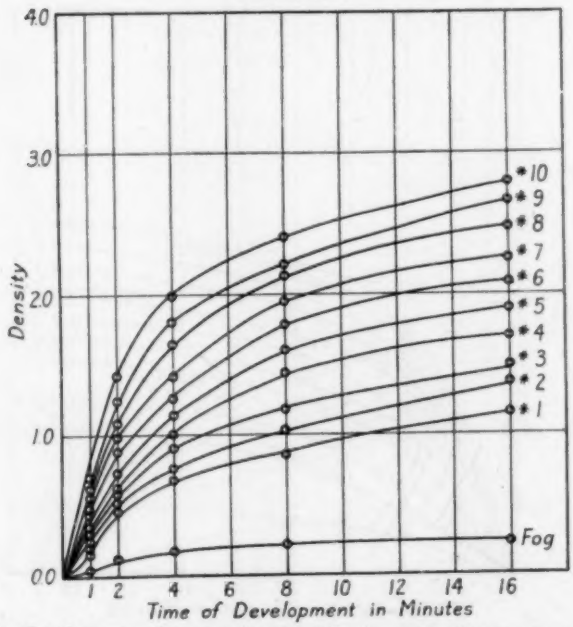
Density-time curves for a pyrogallol developer stirred at 3080 r. p. m.

FIG. 11.



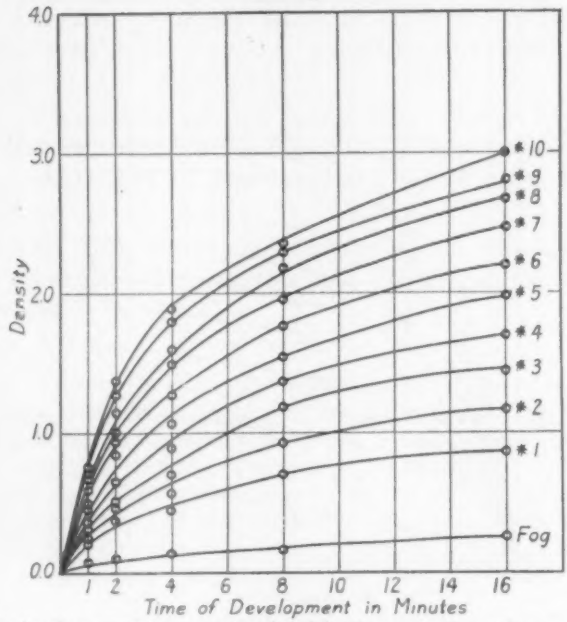
Density-time curves for a p-aminophenol developer stirred at 720 r. p. m.

FIG. 12.



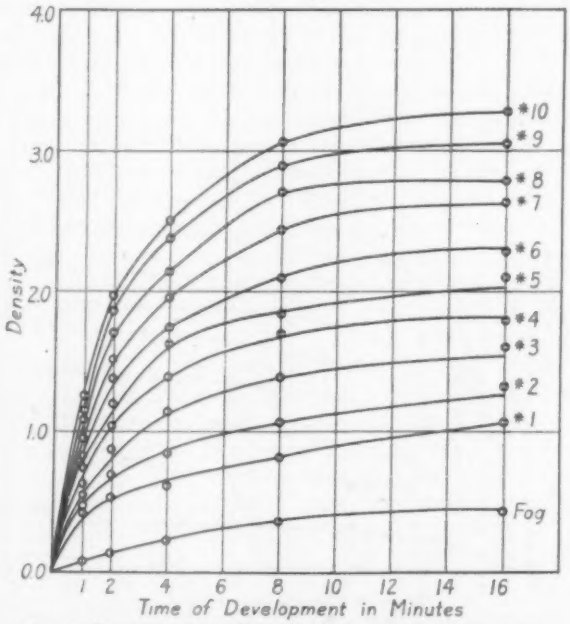
Density-time curves for a p-aminophenol developer stirred at 1540 r. p. m.

FIG. 13.



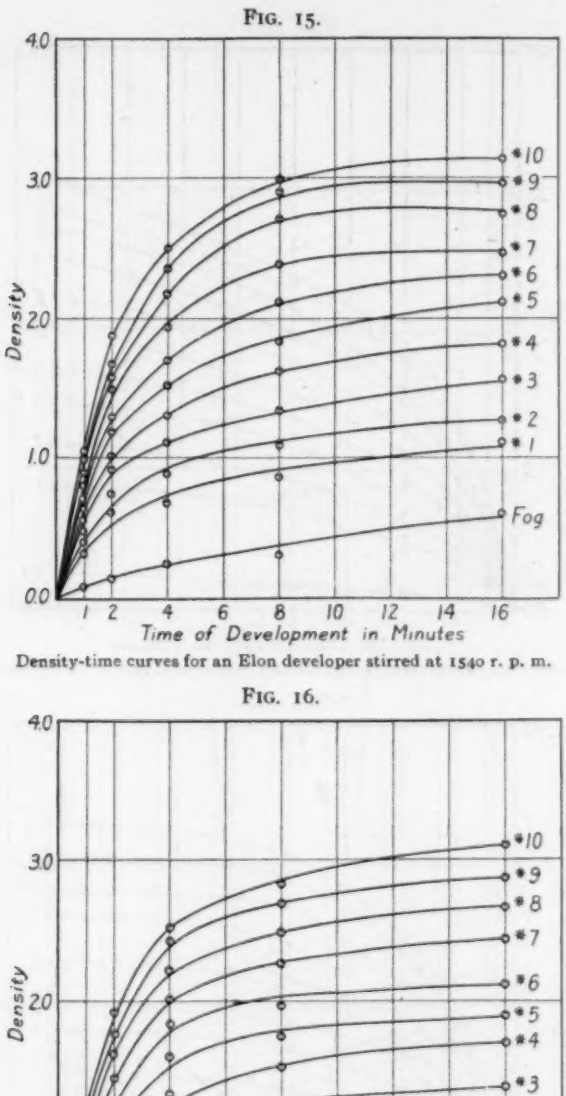
Density-time curves for a p-aminophenol developer stirred at 3080 r. p. m.

FIG. 14.



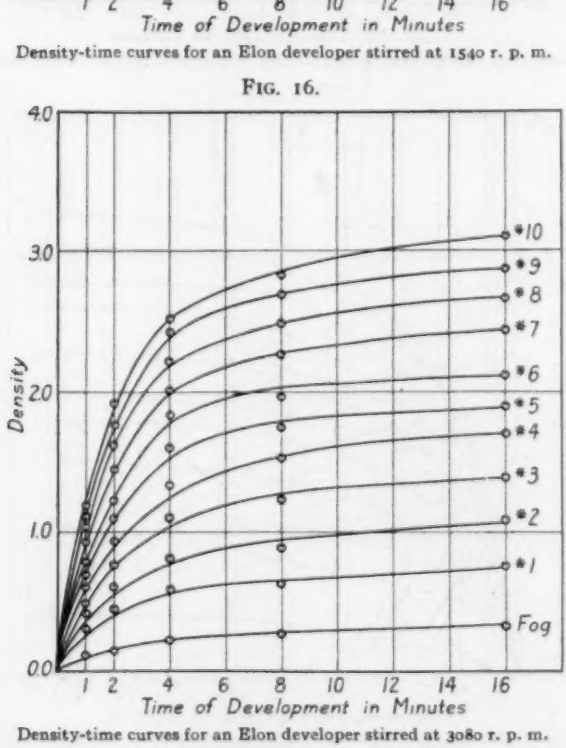
Density-time curves for an Elon developer stirred at 720 r. p. m.

FIG. 15.



Density-time curves for an Elon developer stirred at 1540 r. p. m.

FIG. 16.



Density-time curves for an Elon developer stirred at 3080 r. p. m.

SUMMARY.

(1) Data are given exhibiting the effect of stirring velocity upon photographic development (contrast) up to high velocities, of the order 40 cm. per second.

(2) Data are given showing progressive change in the type of curve (velocity function) for the course of development on passing from developers of low Watkins' factor to those of high Watkins' factor.

(3) This progression is independent of stirring velocity and is determined by constitutional differences in the reducing molecules.

Motor Trucks for Milk Transportation. (Clip Sheet No. 320, U. S. Department of Agriculture, August 11, 1924.)—The motor truck is now the most important agency for transporting milk from producer to city distributor, according to the Bureau of Public Roads. The bureau has recently completed a survey of milk transportation for eight large cities and has found that the motor truck, which first entered the field in 1913, when most of the milk was transported by rail and the remaining portion by wagon, is now the major factor in the field.

Of the total amount of milk delivered to the cities investigated the amounts delivered by motor truck were as follows: Baltimore, 45 per cent.; Philadelphia, 20 per cent.; Cincinnati, 97 per cent.; Detroit, 88 per cent.; Milwaukee, 87 per cent.; St. Paul and Minneapolis, 94 per cent.; and Indianapolis, 94 per cent.

This form of transportation has been of great benefit in developing new milk-producing territory for growing cities and has given the farmers a more satisfactory means of delivering their product. The milk moves directly from the farmer's gate to the city's bottling plant instead of being delivered to the steam or electric railroad station, hauled by rail, and then delivered from the city terminal.

In the Baltimore area a farmer's coöperative trucking association has been organized with a city warehouse, where the milk trucks call for a return load of farmers' supplies.

Peat Produced in the United States in 1923.—The peat produced in the United States in 1923 amounted to 61,355 short tons, valued at $376,834, according to a statement issued by the Department of the Interior, based on figures compiled in the Geological Survey by K. W. Cottrell. The quantity was greater by 675 tons, or less than 1 per cent., than the output in 1922, but the value was $20,895, or 5 per cent., less than the value of the output in 1922.

SPECTROSCOPY AND BOHR'S THEORY OF ATOMIC STRUCTURE.*

BY

PAUL D. FOOTE, Ph.D.

Physicist, Bureau of Standards.

AN interpretation of the structure of atoms must be based upon a vast accumulation of experimental data much of which is at variance with our previous physical conceptions. There is little doubt that an atom may be considered as a miniature planetary system consisting of a positively charged nucleus about which negative electrons revolve. The charge on the nucleus is $+Ze$ where Z is the atomic number of the element, and the number of planetary electrons in a neutral atom must be equal to Z. The mass of the nucleus is so much greater than the combined mass of all the electrons that, except for problems of finer analysis, it may be considered as infinite. The motion of any one electron, therefore, should be determined by the nuclear charge Ze and the perturbing effects of the other electrons. These conclusions are the direct result of experiments on X-rays, investigations of collisions between α-particles and atoms, and spectroscopic analysis.

However, although the atom is a complicated planetary system, it is entirely different from the ordinary planetary systems of astronomy in that its total energy under given external conditions appears to be independent of its past history. All the atoms having nuclei of the same charge and mass are apparently identical. While any continuously variable amount of energy could be communicated to an astronomical system by collision with a sufficiently large meteor, it is found experimentally that in general only perfectly definite quantities of energy may be absorbed by an atom. Furthermore, soon after absorption of some precise amount of energy, which may be abstracted from the kinetic energy of an impacting electron or may be secured by absorption of radiation from an external source, the atom emits this energy as one or

* Presented at a meeting of the Institute held February 14, 1924. Published by permission of the Director of the Bureau of Standards, Department of Commerce.

more monochromatic, spectral lines, and returns to its initial or normal state.

It is impossible to describe here the many experiments in critical potential measurement, excitation of spectral lines by electron impact and by temperature, absorption spectra, X-rays, general spectroscopy, etc., which have necessitated a departure from the usual procedure of the classical electrodynamics and have led to the development of the quantum theory of spectroscopy [1] and to speculations on atomic models. Our present interest is confined to a consideration of the schematic representations of the models which are suggested by spectroscopic data. Even here the amount of evidence is of such a varied nature and so replete with small details that the problem can be discussed only in the most superficial manner.

HYDROGENIC ATOMS.

We shall first consider a hydrogenic [2] type of atom having a positive nuclear charge Ze about which a single electron of negative charge $-e$ revolves. A revolving electron undergoes acceleration, and, according to classical electrodynamics, an accelerated electron radiates energy. An atom of this type therefore could not be permanent but would gradually radiate all of its energy as the electron spiraled into the nucleus.[3] In order to interpret the permanence of such an atom Bohr assumes that an accelerated electron does not radiate. With this assumption, we have the simple two-body problem of classical dynamics. The

[1] Bohr, "The Theory of Spectra and Atomic Constitution," Cambridge University Press. "Line Spectra and Atomic Structure," *Ann. d. Physik.*, **71**, 228–288, 1923. Bohr and Coster, "X-ray Spectra and the Periodic System of the Elements," *ZS. f. Physik.*, **12**, 342–74, 1923. Sommerfeld, "Atomic Structure," English translation, Dutton. Foote and Mohler, "Origin of Spectra," Chemical Catalog Co.

[2] Note this definition of the term "hydrogenic." An atom need not be hydrogen to be hydrogenic.

[3] On the classical theory this would occur unless energy were supplied to the system to compensate for the dissipation by radiation. Van Vleck, in a letter to the writer, states that the absorption of temperature radiation, while not sufficient for complete statistical equilibrium, is still of greater importance than is at first sight apparent. The assumption on the quantum theory that an accelerated electron does not radiate, at least in a "stationary state," has been discussed by Bohr in great detail, both from the physical and philosophical standpoint; *cf.* "On the Application of the Quantum Theory to Atomic Structure," Cambridge Philosophical Society, 1924.

electron revolves in an elliptical orbit of semi-major axis a with a frequency ω expressed by the following relations:

$$\omega = \sqrt{\frac{-2E^3}{\pi^2 e^4 m Z^3}}, \qquad a = \frac{e^2 Z}{-2E} \tag{1}$$

where E is the energy of the system and $-E$ is the work required to remove the electron to an infinite distance, which may be determined experimentally by measurement of the ionization potential. Examples of this simple type of atom are hydrogen, singly ionized helium, doubly ionized lithium, etc. The spectra of the first two are well known, and empirically are found to obey the general formula,

$$\nu = Z^2 R\left[\frac{1}{(n'')^2} - \frac{1}{(n')^2}\right] \tag{2}$$

where ν is the wave number of a spectral line, n'' and n' are integers, and R is the so-called Rydberg constant. If we multiply equation (2) by $-hc$ (h = Planck's constant of action; c = velocity of light) all the terms reduce to the dimensions of energy, and if we assume that one quantum of energy is emitted by an atom during a single process of radiation, the loss of energy must amount to $hc\nu$. Such a condition would obtain if $-Z^2 R\, hc/(n')^2$ represented the energy of the system before the radiation was emitted and $-Z^2 R\, hc/(n'')^2$ the energy after the emission. Let us therefore define the energy of the nth state as follows:

$$\text{Energy of } n\text{th state} = E_n = -\frac{Z^2 R hc}{n^2} \tag{3}$$

Substituting this in equation (1), we obtain for the frequency of revolution of the electron

$$\omega_n = \frac{2Rc Z^2}{n^3}\sqrt{R \cdot \frac{h^2 c}{2\pi^2 e^4 m}} \tag{4}$$

The frequency $c\nu$ of the radiation emitted for values of n'' and n' large compared with their difference Δn, approaches, as is seen from equation (2), the relation

$$\text{Frequency of radiation} = \nu_f = c\nu \doteq \frac{2Rc Z^2}{n^3}\Delta n. \tag{5}$$

If n'' and n' refer to neighboring states, $\Delta n = 1$, and we find on comparison of equations (4) and (5) that the frequency of the emitted radiation approaches the frequency of revolution of the

electron in either state provided the radical in equation (4) is unity, so that

$$R = \frac{2\pi^2 e^4 m}{h^3 c} \tag{6}$$

This later expression is confirmed; the values of the universal constants on the right, determined by methods independent of spectroscopy, yield the empirical or spectroscopic value of R.

From equations (4) and (5) we find that the

$$\text{Frequency of radiation} = \omega_n \Delta n \text{ for large values of } n. \tag{7}$$

The motion of the electron revolving in an elliptical orbit with the nucleus at the focus can be represented by a Fourier analysis as a series of terms containing the fundamental frequency of revolution and all the harmonics or overtones, ω, 2ω, 3ω, etc. On the basis of the classical electrodynamics these frequencies should be emitted simultaneously by the atom. According to the quantum theory, equation (7) shows that, for large values of the integer n, a *single* overtone is emitted during each radiation process, and the complete spectrum is produced by the integrated action of many atoms. While the physical conceptions underlying the two hypotheses are entirely different, there is a statistical correspondence for the small frequencies or long wave-lengths. The quantum theory approaches the classical theory, in its statistical relationships, as the wave-length of the radiation approaches that employed in wireless transmission. An analogous situation occurs in the theory of black-body radiation where the quantum and classical expressions for the energy distribution in the spectrum give the same numerical results in the region of great wave-lengths, while the classical treatment is entirely insufficient for the higher frequencies.

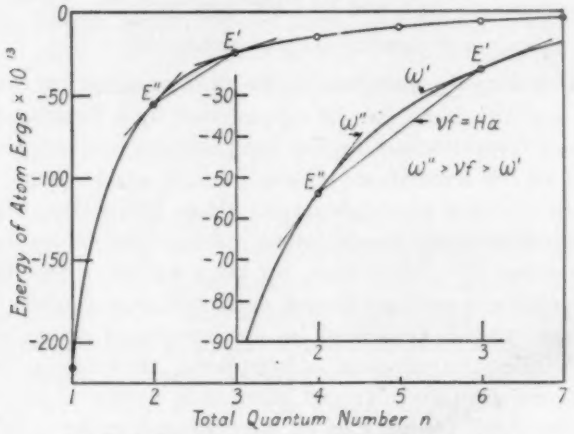
The facts of empirical spectroscopy have therefore led Bohr to the conclusion that a hydrogenic atom always possesses some unique amount of energy given by equation (3), where n is an integer, known as the chief quantum number. From equations (3), (2) and (1) we obtain for the orbital constants

$$E = -h c \nu = -\frac{Z^2 R h c}{n^2}, \qquad a = \frac{e^2}{2 R h c} \frac{n^2}{Z} \tag{8}$$

The quantity ν is the wave number corresponding to the nth variable term in the empirical spectroscopic classification. For hydrogen the series of ν-values are given by R/n^2. The minor

axes of the elliptical orbits may have any magnitude since the energy is determined by the single quantum number n which by equation (1) fixes the value of the major axis only.[4] In the normal state, the hydrogenic atom assumes a configuration where the electron moves on an orbit of the lowest quantum number, as here the energy is a minimum and the stability, from the quantum-

FIG. 1.



Schematic illustration of the correspondence principle.

dynamical standpoint, attains its highest value. This corresponds to $n = 1$ in equation (8) so that the semi-major axis a_h (or radius, since, as we shall see, the orbit must be circular) for the normal hydrogen atom is

$$a_h = \frac{e^2}{2R\,hc} = 5.29 \cdot 10^{-9}\ \text{cm}. \qquad (9)$$

The correspondence between ν, the frequency of the radiation emitted, and ω, the frequency of the revolution of the electron, has been illustrated graphically by Lorentz in his California lectures. In Fig. 1 the ordinates represent energy of the hydrogen atom and the abscissas, the chief quantum number characterizing the state. The plotted circles refer to the energies of the various stationary states, obtained directly from the spectroscopic determinations of the variable terms ν. When the radiation is produced by a transition of the electron between two adjacent

[4] This statement applies for an ideal or hypothetical atom. It will be modified, presently, for the actual hydrogenic atom.

stationary states, the slope of the line, joining these states, divided by h, is the frequency of the emitted radiation. The hydrogen line H_α is indicated on the diagram. The frequency of revolution of the electron in each of the two states concerned is the slope of the tangent to the curve at the corresponding points, divided by h. The slope of the chord is intermediate to the slopes of the two adjacent tangents and the three slopes approach the same value asymtotically as the quantum number increases.

The development so far applies on the assumption of a strictly Coulomb field. Only one fundamental frequency is present, the frequency of revolution of the electron in any particular stationary state, and hence the single quantum number n is sufficient for the fixation of the energy. If in addition to the Coulomb field we have a perturbing central force, an additional frequency is introduced. This new frequency arises in the perturbing action of the extra field which, as can be shown by mathematical analysis, causes a uniform precession of the motion in its orbital plane, the precessional frequency being represented by σ. When two fundamental frequencies occur in the motion, two quantum numbers n and k are required for the fixation of the energy and the characteristics of the orbit. The additional integer k is known as the azimuthal quantum number and $kh/2\pi$ is the total angular momentum of the system.

If the perturbing force is small, the orbit may be described as an ellipse, the major axis of which slowly precesses with the frequency σ. Exactly this state of affairs exists in the hydrogenic atom. The electron describes an elliptical orbit with varying speed, relatively slowly at aphelion and very rapidly at perihelion. On relativistic mechanics the mass of the electron is therefore changing in accordance with the relation $m = m_0/\sqrt{1 - v^2/c^2}$ where v is the speed, c the velocity of light and m_0 the mass at rest. Mathematically the relativistic mechanics may be replaced by Newtonian mechanics with the addition to the Coulomb field of a perturbing central force.[5] The quantum number k made necessary by the precession σ arising in the perturbing field may be introduced by different mathematical methods, all of which lead

[5] Strictly considered, a transformation in the scale of time should be made, as Van Vleck has kindly pointed out to the writer. However, even if we disregard this, the assumption of a perturbing field gives the correct shape of orbit and the correct energy, after quantization, which are the points of chief interest.

to the same conclusions. The electron must revolve on precessing ellipses with definite major and minor axes and the energy of the atom in any stationary state will depend upon both n and k, as follows:

$$E_{n,k} = -\frac{Z^2 R hc}{n^2}\left[1 + \frac{\alpha^2 Z^2}{n^2}\left(\frac{n}{k} - \frac{3}{4}\right) + \cdots\cdots\right] \tag{10}$$

where

$$\alpha^2 = \frac{4\pi^2 e^4}{h^3 c^2} = 5.31 \cdot 10^{-5}$$

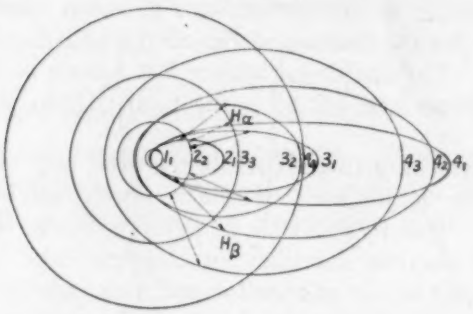
$$\text{Semi-major axis} = a = \frac{e^2}{2R hc}\frac{n^2}{Z} = a_h \frac{n^2}{Z} \tag{11}$$

$$\text{Semi-parameter} = p = \frac{e^2}{2R hc}\frac{k^2}{Z} = a_h \frac{k^2}{Z} \tag{12}$$

$$\text{Semi-minor axis} = b = a\frac{k}{n} \tag{13}$$

Only two of the three equations (11) to (13) are independent; the ellipse may be specified by any two of the constants a, p, and

FIG. 2.



Orbits in hydrogen to $n = 4$.

b. The main portion of the energy is determined by the chief quantum number since the second term in brackets in equation (10) is very small. If now we put the difference in energies for two stationary states equal to $-h\nu$, not only is every line in the spectrum of atomic hydrogen and ionized helium accounted for, but the observed fine structure of the lines may be interpreted. The complex structure of each line as revealed by a spectroscope of very high resolving power is due to the small effect produced by changes in the integer k. The various possible elliptical orbits for the hydrogen atom up to $n = 4$ are shown in Fig. 2. These are

characterized by the notation n_k. The orbit for the normal state is a circle with the designation 1_1. When the electron occupies an orbit of higher quantum number we describe the atom as existing in an excited state. Experiments show that most excited states may be occupied on the average for only 10^{-7} to 10^{-8} seconds.

Up to the present time attempts at quantization have been successful only for motions which are conditionally periodic. A Lissajous figure in which the horizontal and vertical frequencies are incommensurable, and the precessing orbit of the electron in hydrogen are excellent examples of the type of problem which can be treated. As far as kinematics is concerned, each of these motions may be made periodic by imposing proper conditions on the frequencies of the coördinates.

Systems which are thus quantizable have certain generalized coördinates x of the type $x_i = \omega_i t + \delta_i$, where ω_i and δ_i are constants, such that the energy E is a function only of the corresponding generalized momenta, which we shall call $I_1, I_2, \ldots I_r$. Further, these coördinates possess the property that a change of any one of them by unity leaves the configuration of the system unaltered. That is, ω has the significance of an actual frequency of the motion. If we pass from one given configuration to a neighboring one characterized by different values of the I's, the difference in energies of the two systems is given by

$$dE = \frac{\partial E}{\partial I_1} dI_1 + \frac{\partial E}{\partial I_2} dI_2 + \cdots\cdots \frac{\partial E}{\partial I_r} dI_r.$$

Hamilton's equations of the type

$$\frac{\partial E}{\partial p_i} = \dot{q}_i$$

show that

$$\frac{\partial E}{\partial I_i} = \frac{dx_i}{dt} = \omega_i.$$

Therefore

$$dE = \omega_1 dI_1 + \omega_2 dI_2 + \cdots \omega_r dI_r. \qquad (14)$$

In the systems which we shall discuss, the quantities ω_i have the significance of frequencies of revolution of an electron, frequencies of orbital precession, etc.

Bohr's quantum postulates assert that only those states exist in nature for which $I_1 = n_1 h \ldots I_r = n_r h$. Suppose for the

purposes of our calculations that the quantum numbers are continuously variable; then from equation (14)

$$dE = h\omega_1 dn_1 + h\omega_2 dn_2 + \cdots$$

For an atom with two fundamental frequencies ω and σ, this becomes

$$dE = h\omega dn + h\sigma dk \tag{15}$$

Also

$$dE = \frac{\partial E}{\partial n}\, dn + \frac{\partial E}{\partial k}\, dk$$

so that

$$\text{Frequency}^* \text{ of revolution of electron in orbit} = \omega = \frac{1}{h}\frac{\partial E}{\partial n} \tag{16}$$

$$\text{Frequency of precession of major axis} = \sigma = \frac{1}{h}\frac{\partial E}{\partial k} \tag{17}$$

Thus using equation (10) for the energy and calculating $\frac{1}{h}\frac{\partial E}{\partial n}$ we find that

$$\omega = \frac{2Rc\,Z^2}{n^3} \tag{18}$$

which agrees with equation (4) if we recall that the radical there has the value unity. Evaluating in a similar manner the precessional frequency, we obtain,

$$\sigma = \frac{\alpha^2 Rc\,Z^4}{n^3\,k^2} \tag{19}$$

and

$$\omega/\sigma = 2k^2/\alpha^2 Z^2 \tag{20}$$

Table I gives the complete data computed from the preceding formulas for the orbits of hydrogen ($Z = 1$) up to $n = 4$.

The ratio ω/σ is the number of revolutions which the electron makes while the major axis precesses through one complete cycle of 360°. This, as appears from equation (20), is independent of the chief quantum number. For all orbits of azimuthal quantum number $k = 1$, the electron makes about 38,000 revolutions while the major axis precesses once around, or the precession per revolution is about 0.01°. The precession per revolution of the orbits for which $k = 3$ is about 0.001°. Such small precessions obviously can not be represented in Fig. 2. To all practical purposes these orbits are closed ellipses as there drawn.

*ω refers to frequency in a reference system which revolves with the frequency of precession.

TABLE I.

Hydrogen Orbits (Dimensions are in terms of $a_h = 5.286 \cdot 10^{-9}$cm.).

n_k	a	b	p	$\omega \cdot 10^{-14}$	$\sigma \cdot 10^{-8}$	ω/σ
1_1	1	1	1	65.78	1746.	37,700
2_1	4	2	1	8.222	218.3	37,700
2_2	4	4	4	8.222	54.57	150,700
3_1	9	3	1	2.436	64.68	37,700
3_2	9	6	4	2.436	16.17	150,700
3_3	9	9	9	2.436	7.187	339,300
4_1	16	4	1	1.029	27.29	37,700
4_2	16	8	4	1.029	6.822	150,800
4_3	16	12	9	1.029	3.032	339,300
4_4	16	16	16	1.029	1.705	603,200

ATOMS WITH SEVERAL ELECTRONS.

We have seen that the various spectral lines of hydrogen or ionized helium are obtained by differences of two variable terms of the type $\nu = RZ^2/n^2$. The lines of the more complicated elements also have been found empirically to be given by the differences between two variable terms which may be expressed with a fair degree of approximation as follows:

$$\nu = \frac{RZ^2}{(n+\varphi)^2} \tag{21}$$

However, instead of having a single group of terms, as with hydrogen, several different sequences are found corresponding to different values of the constant φ. This condition is also true for hydrogen if we take account of the fine structure of each individual line. The various sets of components of the fine structure, due to relativity or to a perturbing central force, in a hydrogenic atom, are explained by changes in the quantum number k of equation (10). These differences in hydrogen or helium are too small for observation with an ordinary spectroscope, but with the more complicated atoms they become very large, indicating the presence of a perturbing force *many times greater than that which may arise from relativity of mass. Such a perturbing field is due to the presence of other electrons in the atom.*

By the methods of empirical spectroscopy the different variable terms in complicated spectra have been correlated in sequences of the type illustrated by equation (21) and for convenience of reference names have been assigned to each sequence. Thus in the

alkali spectra we have the *ms, mp, md, mf, mg, etc.*, sequences of variable terms, where m is an integer, but one which differs from the value of n in equation (21), since these terms were named before their physical significance was apparent. As an illustration, the variable terms for the lithium spectrum are listed in Table II.

TABLE II.

Variable Terms of Lithium Spectrum.

ms.	ν	*mp.*	ν	*md.*	ν	*mf.*	ν
1*s*	43484.45						
2*s*	16280.53	2*p*	28581.36				
3*s*	8474.15	3*p*	12559.93	3*d*	12202.50		
4*s*	5186.87	4*p*	7016.99	4*d*	6862.53	4*f*	6855.49
5*s*	3499.59	5*p*	4472.85	5*d*	4389.25	5*f*	4381.23
6*s*	2535.35	6*p*	3094.45	6*d*	3046.93	6*f*	– – –

Combinations between these variable terms (and higher terms in the sequences, which have been omitted from the table) give every line of the lithium arc spectrum. For example, the red lithium line λ 6708 Å. is $1s - 2p$. However, certain combinations do not appear, at least in the absence of an outside electric or magnetic field. The same state of affairs is found upon a closer examination of the fine structure of lines emitted by hydrogenic atoms. Here certain components are absent which according to equation (10) correspond to *changes* in the quantum numbers k differing from ± 1. The non-existence of such components under ordinary excitation is due to a restriction on the amount of angular momentum which may be carried away from the atom by a single quantum of radiation. The principle of conservation of angular momentum is held valid for the system composed of the atom and the quantum. By applying this principle to the spectra of non-hydrogenic atoms, it is possible to assign a definite azimuthal quantum number k to each group or sequence of variable terms, as follows:

Term.	k.
ms	1
mp	2
md	3
mf	4
mg	5

Hence except in very strong electrical discharges, where disturbances arise on account of the presence of the applied field or the fields of neighboring ions, we should not expect to observe lines of the type $\nu = ms - m'd$, $\nu = mp - m'f$, $\nu = ms - m's$ since for these the change in k is two units or zero. This observation is consistent with experiment.

An atom of an alkali metal has one electron which may be readily removed. This is shown by the existence of numerous compounds in which sodium, for example, occurs as the positively charged constituent, having a positive charge of unity, as is proved by electrolytic data. The fact is also confirmed by the ease with which sodium vapor may be ionized with the formation of singly charged positive ions, and by a vast amount of other evidence of varied nature. It is relatively difficult to produce double ionization in sodium. The fact that an electron may be readily removed from an alkali atom suggests that it revolves in an orbit a considerable portion of which extends beyond or protrudes from the underlying structures traced out by the other revolving electrons. If this valence electron could revolve in an orbit which at all points were relatively far-distant from the rest of the atom (or atom-kernel, as it is termed), it would be acted upon by practically the same attracting force as exists in the hydrogen atom for a corresponding orbit. At sufficiently large distances, the ten remaining electrons of sodium and the nuclear charge of 11 should give practically a Coulomb field with a net nuclear charge of unity. Changes in the stationary states of the atom produced by transitions of the valence electron between two very large orbits should therefore give rise to spectral lines which do not differ materially from those found in hydrogen.

The semi-parameters for hydrogen orbits for which $k = 4$ and 3, as follows directly from equation (11) where $Z = 1$, are $16a_h$ and $9a_h$, respectively. An upper limit for the radius of the sodium ion is obtained from X-ray crystal analysis, by which the distance between the sodium ions in a crystal such as NaCl may be directly measured. Davey's observations show that the ion-radius is not greater than $2.2a_h$. Since the semi-parameters for all orbits characterized by $k = 3$ or 4 are several times this, one may conclude that in the stationary states corresponding to the *md* and *mf* terms, the valence electron revolves far outside the atom-kernel in a hydrogenic field of practically unit charge.

The next element in the periodic table is magnesium, which has two valence electrons. If one of these is removed the structure should resemble that of sodium. Interorbital transitions of the remaining valence electron give rise to the first spark spectrum or to the spectrum of Type II, the spectrum of Type I being that of the neutral atom. If the valence electron of sodium may revolve in a field of one charge, the single valence electron of ionized magnesium should revolve, for large orbits, in a field of two charges, since the net kernel charge of magnesium$^+$ is $+2e$. Accordingly, as follows from equation (8), the wave numbers for the *md* and *mf* terms of MgII should be 4 times the corresponding terms for NaI. The justification for this conclusion is shown by Table III, in which the empirically determined terms are tabulated.

TABLE III.

Variable Terms in NaI and MgII.

Term.	NaI	MgII	Ratio.
3*d*	12274.46	49773.4	4.055
4*d*	6896.82	27953.9	4.053
5*d*	4411.48	17844.8	4.045
6*d*	3061.95	12364.9	4.038
4*f*	6858.62	27464.82	4.004
5*f*	4388.62	17574.57	4.005
6*f*	3039.73	12200.86	4.014

The field being practically hydrogenic, each term of Table III for NaI should correspond numerically with some hydrogen term, and each term for MgII should correspond to some term of ionized helium, HeII. Table IV illustrates this correspondence.

TABLE IV.

Term.	NaI	H	*n*	Term.	MgII	HeII	*n*
3*d*	12274	12186	3	3*d*	49773	48765	3
4*d*	6897	6855	4	4*d*	27954	27431	4
5*d*	4411	4387	5	5*d*	17845	17556	5
6*d*	3062	3047	6	6*d*	12365	12191	6
4*f*	6859	6855	4	4*f*	27465	27431	4
5*f*	4389	4387	5	5*f*	17575	17556	5
6*f*	3040	3047	6	6*f*	12201	12191	6

The close agreement between these terms and the corresponding ones in H or HeII, for which the chief quantum numbers *n*

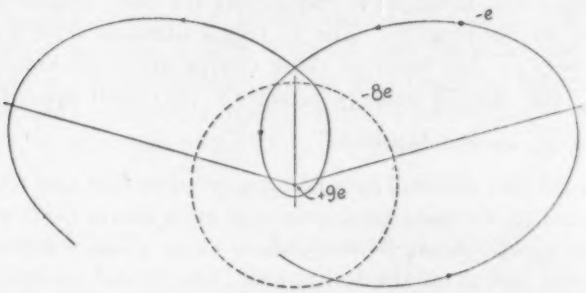
are known from equation (8), justifies the assignment of the same chief quantum numbers to the *md* and *mf* terms of NaI and MgII. Since by equation (13) the minimum value of n possible is $n = k$, in which case the orbit is a circle, we see that this assignment of chief quantum numbers for the *md* and *mf* terms is consistent with the earlier allocation of the azimuthal quantum numbers k to these terms. The *md* sequences of NaI and MgII should begin with the $3d$ terms listed, as is empirically the case, and these orbits are circles of the type 3_3. The $4f$ terms likewise refer to circles of the type 4_4. The radii of these circles are approximately $9a_h$ and $16a_h$ for the $3d$ and $4f$ terms of NaI and approximately $\frac{9}{2}\,a_h$ and $\frac{16}{2}\,a_h$ for MgII.

Provided that the field may be considered as that due to a single positive charge, the semi-parameter for an *ms* term corresponding to $k = 1$, is a_h, as follows from equation (12). This is considerably less than the radius of the sodium ion, and would be still smaller if the field is greater than unity. Accordingly one may conclude that the orbits corresponding to the *ms* terms do not encircle the kernel but penetrate into its structure. We must therefore distinguish between two types of orbit for the valence electron, those which penetrate the inner structure and those which entirely encircle it.

The kernel of the sodium atom resembles the element of next lower atomic number, the rare gas neon with ten electrons. As shown by X-ray data, two of these are bound closely to the nucleus, in a configuration resembling helium, and the other eight revolve in larger orbits. Data from many sources suggest that these eight outer electrons pair off symmetrically as far as their effects a short distance from the atom are concerned, so that the field just outside the neutral neon atom decreases inversely as a high power of the distance. Accordingly the field just outside the sodium ion is practically equivalent to that of a unit nuclear charge. For purposes of rough computation we may therefore represent the sodium atom with the valence electron on a $1s$ orbit in the following manner. The two innermost electrons partially neutralize the nuclear charge, leaving a net nuclear charge of +9. This is surrounded by a rigid shell of negative charge representing the eight outer electrons of the kernel. The $1s$ orbit penetrates this shell as illustrated in Fig. 3. Outside the shell the valence

electron is acted upon by unit positive charge and the field is strictly of the Coulomb or hydrogen type. After the electron penetrates the shell, it is subjected to a Coulomb field due to a positive charge of nine units. Such orbits are mathematically calculable and have the general form illustrated. The complete orbit consists of a series of outer and inner loops, each loop being

FIG. 3.



Schematic representation of atom as a nuclear charge surrounded by a spherical shell of electricity into which the valence electron penetrates.

elliptical. Precession of the orbit occurs entirely within the uniform shell of charge.

If the valence electron is removed while traversing the outer loop, or at the instant it reaches aphelion, the work done must be practically equal to the negative of the total energy of this electron *at that instant,* because its removal from the remote part of the orbit can produce little effect upon the rest of the configuration.[7] The work of ionization, however, is $hc\nu$ where ν is the wave number corresponding to the orbit concerned. For example, the ionization potential is a measure of the amount of work required to remove the valence electron from the orbit occupied in the normal or unexcited state of the atom. This corresponds to the highest wave number in the spectrum, for the alkalies, the $1s$ term, as illustrated in Table V.

Since in the outer loop the valence electron itself actually possesses the energy $-hc\nu$ and is moving in a Coulomb field of unit charge, this outer loop must have the dimensions of a *hypothetical* elliptical orbit in hydrogen corresponding to the same energy. Such an orbit in hydrogen would be characterized by a

[7] No effect would be produced were the shell actually rigid and fixed.

TABLE V.

Observed and Computed Ionization Potential.

Element.	Ionization Potential in Volts.	
	Computed from 1s.	Observed.
Li	5.37	—
Na	5.12	5.13
K	4.32	4.1
Rb	4.16	4.1
Cs	3.88	3.9

non-integral chief quantum number n^* such that R/n^{*2} gives the actual value of ν for the term in the sodium spectrum. The dimensions of the outer loop accordingly follow directly from equations (11) and (13)

$$\text{Semi-major axis} = a = a_h n^{*2} \tag{22}$$

$$\text{Semi-minor axis} = b = ak/n^* \tag{23}$$

The value of k corresponds to the term under consideration, 1 for the *ms* terms, 2 for the *mp* terms, etc.

DERIVATION OF RYDBERG FORMULA.

Assuming that the force exerted by the atom-kernel on the valence electron is approximately central, the precession is maintained in the same orbital plane, and two fundamental frequencies are present, ω the frequency of revolution of the electron and σ the frequency of precession. The energy is therefore a function of two quantum numbrs n and k, so that

$$dE = \frac{\partial E}{\partial n}\,dn + \frac{\partial E}{\partial k}\,dk \tag{24}$$

and

$$= h\omega dn + h\sigma dk \qquad \text{by equation (15)} \tag{25}$$

For a true Keplerian ellipse of the same energy we have by equation (8)

and

$$E = -\frac{Rhc}{n^{*2}} \tag{26}$$

$$dE = \frac{\partial E}{\partial n^*}\,dn^* = h\omega^* dn^* \tag{27}$$

where ω^* is the frequency of revolution of the electron on the hypothetical n^* orbit in hydrogen.

Most of the perturbation from a true Keplerian ellipse occurs

near perihelion, and since the orbit in this region is traversed in a very small fraction of the time required to make one complete revolution, the frequency ω^* is practically equivalent to the actual frequency ω. Equating equations (27) and (25) we have

$$h\omega^* dn^* = h\omega dn^* = h\omega dn + h\sigma dk$$

and

$$dn^* = dn + \frac{\sigma}{\omega} dk \tag{28}$$

also

$$dn^* = \frac{\partial n^*}{\partial n} dn + \frac{\partial n^*}{\partial k} dk \tag{29}$$

so that the solution of equation (28) is

$$n^* = n + \varphi(k) \tag{30}$$

where $\varphi(k)$ does not involve n.

Substituting this value of n^* in equation (26) we obtain

$$E = -\frac{Rhc}{n^{*2}} = -\frac{Rhc}{[n + \varphi(k)]^2} \tag{31}$$

On putting the energy $E = -h\nu$ we have

$$\nu = \frac{R}{[n + \varphi(k)]^2} = \frac{R}{n^{*2}} \tag{32}$$

which is identical with equation (21), the empirical formula originally suggested by Rydberg.[8] The quantity n^* is called the effective quantum number and is always less than Bohr's assignment for the chief quantum number n, so that $\varphi(k)$ is a negative constant for any particular value of k. Physically this is evident, because the work of ionization, $-E$, is increased, over that necessary for the corresponding state in hydrogen, since for a portion of the time the electron revolves in a field much greater than that due to unit positive charge.

ASSIGNMENT OF CHIEF QUANTUM NUMBERS.

The methods employed for the assignment of the chief quantum numbers are of such a general and complex nature that they can not be discussed with satisfaction in this brief report, but the details are found in Bohr's original papers. We have seen that terms which correspond to orbits of large dimensions, especially of large parameter, and azimuthal quantum number, are approxi-

[8] *Cf.* Bohr, *Proc. Lond. Phys. Soc.*, **35**, 296, 1923.

mately hydrogenic, so that by direct comparison with the corresponding term in hydrogen, ionized helium, etc., values of the chief quantum number may be assigned with considerable certainty.

Bohr's complete scheme of atomic structure requires a general similarity of the internal arrangement of the electrons in the atoms. Thus in the building of any element, starting with the nucleus alone, the first electron assumes the hydrogenic structure, revolving in a 1_1 unit. Addition of the second electron produces a configuration similar to helium with two electrons each in a 1_1 orbit. This completes the K-shell for all elements. The fact that the slope of the Moseley diagram for the K X-ray limits is practically unity shows that the chief quantum number for the electrons in the K-shells of all the elements is 1. The third electron added in the building of any element should produce the lithium configuration, and the spectrum of lithium shows that the electron must revolve in an orbit for which $n=2$. This initiates the development of the L-shell and the Moseley diagram for the L X-ray limits has a slope of approximately $1/2$. The L-shell is completed with neon which possesses two electrons in the K-shell and eight in the L-shell. The eleventh electron in all succeeding atoms, the first of which is sodium, occupies a three-quanta orbit and belongs to the M-shell. The slope of the Moseley diagram for the M-series is approximately $1/3$. Proceeding in this general way Bohr was able to assign chief quantum numbers to the various electrons in the atoms as shown by Fig. 4.

Certain irregularities occur in the scheme. Thus while the eleventh electron in every atom revolves in a three-quanta orbit, the nineteenth electron, occurring first with potassium in a four-quanta orbit, becomes bound in a three-quanta orbit in heavier elements, probably beginning with the twenty-first element, scandium. Evidence for this further development of an underlying shell may be read from the spectra of potassium and ionized calcium. Other interesting irregularities occur, one of which predicts the presence of all the rare earths. It will be noted from Fig. 4 that the valence electrons in the normal state all revolve in orbits characterized by values of n equal to the period of the element in the Mendeléeff table.

By assuming a model for an alkali atom such as illustrated

FIG. 4.

Number of Electrons in Different n_k Orbits.

Period.	Z	1_1	2_1 2_2	3_1 3_2 3_3	4_1 4_2 4_3 4_4	5_1 5_2 5_3 5_4 5_5	6_1 6_2 6_3 6_4 6_5 6_6	7_1 7_2
1	1 H	1						
	2 He	2						
2	3 Li	2	1					
	4 Be	2	2					
	5 B	2	2 (1)					
	– –	–	– –					
	10 Ne	2	4 4					
3	11 Na	2	4 4	1				
	12 Mg	2	4 4	2				
	13 Al	2	4 4	2 1				
	– –	–	– –	– –				
	18 A	2	4 4	4 4				
4	19 K	2	4 4	4 4	1			
	20 Ca	2	4 4	4 4	2			
	21 Sc	2	4 4	4 4 1	(2)			
	22 Ti	2	4 4	4 4 2	(2)			
	– –	–	– –	– – –	–			
	29 Cu	2	4 4	6 6 6	1			
	30 Zn	2	4 4	6 6 6	2			
	31 Ga	2	4 4	6 6 6	2 1			
	– –	–	– –	– – –	– –			
	36 Kr	2	4 4	6 6 6	4 4			
5	37 Rb	2	4 4	6 6 6	4 4	1		
	38 Sr	2	4 4	6 6 6	4 4	2		
	39 Y	2	4 4	6 6 6	4 4 1	(2)		
	40 Zr	2	4 4	6 6 6	4 4 2	(2)		
	– –	–	– –	– – –	– – –	–		
	47 Ag	2	4 4	6 6 6	6 6 6	1		
	48 Cd	2	4 4	6 6 6	6 6 6	2		
	49 In	2	4 4	6 6 6	6 6 6	2 1		
	– –	–	– –	– – –	– – –	– –		
	54 Xe	2	4 4	6 6 6	6 6 6	4 4		
6	55 Cs	2	4 4	6 6 6	6 6 6	4 4	1	
	56 Ba	2	4 4	6 6 6	6 6 6	4 4	2	
	57 La	2	4 4	6 6 6	6 6 6	4 4 1	(2)	
	58 Ce	2	4 4	6 6 6	6 6 6 1	4 4 1	(2)	
	59 Pr	2	4 4	6 6 6	6 6 6 2	4 4 1	(2)	
	– –	–	– –	– – –	– – – –	– – –	–	
	71 Lu	2	4 4	6 6 6	8 8 8 8	4 4 1	(2)	
	72 Hf	2	4 4	6 6 6	8 8 8 8	4 4 2	(2)	
	– –	–	– –	– – –	– – – –	– – –	–	
	79 Au	2	4 4	6 6 6	8 8 8 8	6 6 6	1	
	80 Hg	2	4 4	6 6 6	8 8 8 8	6 6 6	2	
	81 Tl	2	4 4	6 6 6	8 8 8 8	6 6 6	2 1	
	– –	–	– –	– – –	– – – –	– – –	– –	
	86 Nt	2	4 4	6 6 6	8 8 8 8	6 6 6	4 4	
7	87 –	2	4 4	6 6 6	8 8 8 8	6 6 6	4 4	1
	88 Ra	2	4 4	6 6 6	8 8 8 8	6 6 6	4 4	2
	89 Ac	2	4 4	6 6 6	8 8 8 8	6 6 6	4 4 1	(2)
	90 Th	2	4 4	6 6 6	8 8 8 8	6 6 6	4 4 2	(2)
	– –	–	– –	– – –	– – – –	– – –	– – –	–
	118 (?)	2	4 4	6 6 6	8 8 8 8	8 8 8 8	6 6 6	4 4

Bohr's assignment of quantum numbers for the various elements.

in Fig. 3, it is possible to compute directly the value of n necessary in order that the ionization potential or the work required to remove the valence electron of an alkali atom from any orbit whatever, which penetrates the inner shell, shall be numerically equal to the energy of the electron in this orbit. Such values are in approximate agreement with Bohr's scheme.[9]

(To be Concluded.)

Sodium Tungstates.—EDGAR F. SMITH and his pupils at the John Harrison Laboratory of Chemistry of the University of Pennsylvania, in the course of years, have made many researches on tungsten, its atomic weight, and its compounds. The latest research in this series is a study of the sodium tungstates by Doctor Smith. In a brochure of twenty-three pages (Philadelphia, 1924) he reports the results of over 700 experiments made to ascertain the composition of these salts. In the literature, mention is made of seven sodium tungstates produced in aqueous solution, the ratio of sodium oxide to tungstic anhydride ($Na_2O : WO_3$) being 1 : 1, 1 : 2, 3 : 7, 5 : 12, 4 : 10, 1 : 3, and 1 : 4, respectively. The normal tungstate has the ratio 1 : 1, the para tungstate the ratio 5 : 12, and the meta tungstate the ratio 1 : 4. Doctor Smith finds that the normal tungstate and the meta tungstate are the extremes of the series, and, by their union, form certain intermediate tungstates having the ratios 3 : 7, 5 : 12, and 4 : 10, respectively. This fact has been demonstrated by analysis of the fused intermediate tungstates, by their hydrolysis, and by their synthesis. Sodium tungstates of the ratio 1 : 2 and 1 : 3 do not exist, probably on account of their ready hydrolysis. In the course of this research, the discovery was made that, when a dehydrated tungstate is exposed to the hot vapors of pure carbon tetrachloride, the tungstic anhydride is completely volatilized; thus anhydrous normal sodium tungstate yields a residue of sodium chloride. J. S. H.

Spitzbergen Coal.—A brief item in *Notes and Queries* (1924, 147, 93) abstracted from *The Scotsman* gives an account of recent investigations into the coal deposits of this northern region. Dr. W. S. Bruce obtained specimens in 1896, but they were pronounced to be Tertiary deposits and were regarded as of little value. Presumably they were more of the nature of lignite than of the familiar soft coals, but later observers made somewhat more encouraging reports, inasmuch as first American exploiters and now Norwegians have undertaken the mining of the deposits. It is also noted that near the coast are deposits of a very fine grade of gypsum which may be a valuable article of export. H. L.

[9] Schrodinger, *ZS. f. Physik.*, **4**, 347, 1921. Fues, *ZS. f. Physik.*, **11**, 364, 1922. Van Urk, *ZS. f. Physik.*, **13**, 268, 1923.

PRESENTATION OF THE FRANKLIN MEDAL AND CERTIFICATE OF HONORARY MEMBERSHIP,

May 21, 1924.

AT the Stated Meeting of the Committee on Science and the Arts, held January 2, 1924, the following resolutions were adopted:

"*Resolved,* That The Franklin Medal be awarded to Sir Ernest Rutherford in recognition of successful researches, signally contributing to the present state of knowledge of the elements, their constitution and relationships."

"*Resolved,* That The Franklin Medal be awarded to Dr. Edward Weston in recognition of discoveries and inventions in the field of electricity, fundamentally contributing to the establishment of the electric art."

STATED MEETING

WEDNESDAY, MAY 21, 1924

3.30 O'CLOCK

PROGRAMME

STATEMENT RELATIVE TO THE WORK OF

SIR ERNEST RUTHERFORD, F.R.S.

CAVENDISH PROFESSOR OF PHYSICS, CAMBRIDGE UNIVERSITY

CAMBRIDGE, ENGLAND

BY

DR. JOSEPH S. AMES

DEAN, THE JOHNS HOPKINS UNIVERSITY

BALTIMORE, MARYLAND

PRESENTATION OF

THE FRANKLIN MEDAL

AND

CERTIFICATE OF HONORARY MEMBERSHIP

TO

H. G. CHILTON, ESQUIRE, C.M.G.

COUNSELLOR OF THE BRITISH EMBASSY

WASHINGTON, D. C.

ON BEHALF OF HIS BRITANNIC MAJESTY'S GOVERNMENT

FOR

SIR ERNEST RUTHERFORD

STATEMENT RELATIVE TO THE WORK OF

EDWARD WESTON, D.Sc., LL.D.

NEWARK, NEW JERSEY

PRESIDENT, THE WESTON ELECTRICAL INSTRUMENT COMPANY

BY

FRANK J. SPRAGUE, D.Sc., LL.D.

NEW YORK CITY

PRESENTATION OF

THE FRANKLIN MEDAL

AND

CERTIFICATE OF HONORARY MEMBERSHIP

TO

DR. EDWARD WESTON

PAPERS

EARLY DAYS IN RADIO-ACTIVITY

SIR ERNEST RUTHERFORD, F.R.S.

READ BY DR. JOSEPH S. AMES

SOME ELECTRICAL REMINISCENCES

DR. EDWARD WESTON

THE PRESENTATION OF THE FRANKLIN MEDAL AND CERTIFICATE OF HONORARY MEMBERSHIP TO SIR ERNEST RUTHERFORD AND DR. EDWARD WESTON.

IN calling the meeting to order the President of the Institute announced that the business of the meeting would be the annual presentation of the Institute's highest award, The Franklin Medal, in recognition of distinguished scientific and technical achievements and recognized Dr. Joseph S. Ames, Dean, Johns Hopkins University, who made the following statement relative to the work of Sir Ernest Rutherford:

Mr. Chairman:

Your Committee charged with the responsibility of selecting from the scientists of the world one worthy of receiving The Franklin Medal are to be congratulated upon their decision for this year, and I appreciate highly the honour and privilege of taking part in this ceremony. Professor Sir Ernest Rutherford, F.R.S., to whom the medal has been awarded "in recognition of successful researches, signally contributing to the present state of knowledge of the elements, their constitution and relationship," is the leading investigator in his chosen field of physics, an inspiring director of a great laboratory, a loyal servant of the British Empire. We all regret that his university duties at Cambridge make it impossible for him to be here to-day to receive the medal in person, but His Britannic Majesty's representative will receive it and will see that it is transmitted officially to England. Before, however, I present to you, Sir, this representative, I beg to say a few words in appreciation of the contributions to science made by Rutherford and also something in regard to him as a man.

Sir Ernest Rutherford was born in a distant colony of Great Britain, in New Zealand, in the year 1871, so that we must still regard him as a man young in years; and those of us who know him personally know the youthful vigor of his mind and spirit. After receiving his early education in his native country, he went at once to the Cavendish Laboratory in Cambridge, England, then under the direction of Professor J. J. Thomson. Here he received his baccalaureate degree in 1897. He stayed on in the laboratory for a year, and was then called to become MacDonald Professor of Physics in McGill University, Montreal. There were many candidates for this chair, and I remember well congratulating

Principal Peterson upon his wisdom in having selected one who even at that time gave every indication of being one of the great experimental physicists of his generation. After a few years at McGill, years full of productive work, to which his paper prepared for to-day will refer, he was called to Manchester University, and later, when Thomson resigned the Cavendish chair at Cambridge, he became, practically automatically, his successor. There could not have been any other. During the World War he did distinguished service for his country and, in fact, for all the Allies, as a member of the Inventions Board. He has been honored by all the learned societies of the world, and early in his career was the recipient of the Nobel Prize. As the Director of the Cavendish Laboratory he has been surrounded by a group of men, colleagues and students, all drawing their inspiration from him. He is endowed by nature with that rare gift, unselfishness, without which no man can ever be the head of a laboratory. He gives freely of his ideas and of his inspired thoughts to all his students. As he himself said to me last year, when we were talking of a man who kept his best problems for himself, "Why, a man with students must be generous, he must even give the best he has." It is no wonder that with such a character men flock to his laboratory from every quarter of the globe.

As an investigator, Rutherford has always had a clear vision of the way ahead of him, and has never entered a blind trail. His general knowledge of physical principles is so sound that he can follow his intuition; and he has the bravery to go forward into unknown fields, designing his own theories and methods to advance his knowledge. His name will ever be associated with one of the most important subjects of modern science, the structure of the nucleus of atoms. As is known to everyone to-day, the physicist has a definite picture in his mind of an atom. This, in its main features, is very simple. There is a minute central portion called the nucleus, which contains practically all the mass of the atom, and around this revolve one or more other particles called electrons. Each of these electrons has an orbit around the nucleus, not unlike the orbit of a planet around the sun. This picture we owe to Rutherford. It has been proved by Sir J. J. Thomson that these electrons are all alike, regardless of the nature of the atom of which they form a part; and, largely owing to the genius of Bohr and to the labors of Sommerfeld and others, law

and order of a fairly definite nature can now be assigned to the positions and motions of the electrons in any kind of atom. But, while the electrons are all identical, the nuclei of different atoms are all different. Thus a hydrogen atom has a definite nucleus and one electron; a helium atom has a definite nucleus and two electrons; and so on, until we come to the heaviest atom known, that of uranium, which has a heavy nucleus and ninety-two electrons revolving around it. Rutherford's greatest contributions to knowledge have been in connection with the structure of the nucleus of the various atoms; he was the first to convince us that it was made up of parts, and he is the only one, in fact, who has obtained experimental knowledge as to the nature of these parts.

Back in 1898 when I spent a day with Rutherford in the Cavendish Laboratory he was working on the nature of the radiations from uranium which had recently been discovered by Becquerel, and he had succeeded in proving that there were two types of radiations, called α- and β-rays. Even at this time he had a definite conviction as to their nature, a conviction soon verified by direct experiment. The α-rays were shown to be positively charged particles, while the β-rays were negatively charged and much lighter in weight. When Rutherford came to McGill University, he extended his studies to the investigation of thorium and radium, the new radio-active substances recently discovered by the Curies, and, in an amazingly short space of time, he had unravelled the mystery of these remarkable substances. He pictured a spontaneous disintegration of radio-active atoms, a process by which in a definite interval of time a certain proportion of the atoms of a piece of uranium, say, emit α- or β-particles, thus being transformed into atoms of a different kind; then these are transformed similarly into other atoms, etc. During his stay at McGill and again at Manchester, he pursued this investigation, until finally the story, as wonderful as a romance, was told. Even from the beginning, Rutherford had been convinced that these α- and β-particles, which play such a part in radio-active disintegrations, came out from the innermost part of the atom; and, therefore, when the planetary model of an atom was shown by him to correspond closely with reality, he spoke of these particles as having been ejected from the nucleus. This led him at once to the investigation of the structure of the nuclei

of all atoms, not necessarily those of the radio-active ones. Returning for a moment to the hydrogen atom, I have said before that here we have one electron revolving around a nucleus. This particular nucleus is called a proton. Again, the helium atom has two electrons revolving around a nucleus, which, as Rutherford proved, is identical with the α-particles emitted by radio-active atoms. When other atoms were investigated, Rutherford showed that we could be justified in believing that all nuclei were made up of electrons, protons and α-particles, a most remarkable simplification of nature. But he indicated a still greater simplification by considering the α-particle as itself made up of parts; and we now believe that each such particle is composed of four protons and two electrons. So that to-day, instead of thinking of ninety-two distinct kinds of matter, corresponding to the number of different elements, we speak of only two, electrons and protons. This concept of nature should, I think, be credited to Rutherford; its importance cannot be overestimated.

I could call attention to other striking results of Rutherford's brilliant series of investigations on α- and β-particles; but, in the few minutes allotted me, I wish to emphasize his close connection with this country. Not only was he the professor of physics at McGill University and therefore almost one of ourselves, but he has been for over twenty years a member of the American Physical Society and has taken part in many of its meetings. His first physical investigation in the Cavendish Laboratory was based directly upon an early observation of Joseph Henry made at Princeton, an observation which in fact was the earliest known case of wireless telegraphy. When he was at McGill, one of his most striking discoveries concerning radio-activity was made in collaboration with Doctor Owens, the distinguished Secretary of this Institute. Again, he more than anyone else has given an answer to the question of the ultimate nature of electrically charged bodies, the question which was always in Franklin's mind.

I may have conveyed to you some appreciation of Rutherford's great contributions to science and may have shown why the decision of the Institute to award him the highest honour in its power to give is justified, but I despair of making you realize how his personal qualities, his unselfishness, his simplicity, his enthusiasm have endeared him to his friends.

Mr. Chairman, it is with the greatest pleasure that I present

to you the Hon. H. G. Chilton, Counsellor of the British Embassy in Washington, who will see that The Franklin Medal awarded to Sir Ernest Rutherford is placed in his hands.

The President then said:

Mr. Chilton, I have the honour to present to you for transmission to Sir Ernest Rutherford The Franklin Medal, the highest award in the gift of the Institute, and Certificate of Honorary Membership in this Institute.

Mr. Chilton, in accepting the Medal and the Certificate of Honorary Membership, said:

Mr. Chairman, Ladies and Gentlemen:

Sir Esme Howard, His Majesty's Ambassador, has begged me to convey to you an expression of his sincere regret that he is unable to be present this afternoon. I need hardly say what a privilege and pleasure it is for me to have been deputed to represent him for the purpose of receiving The Franklin Medal and Certificate of Honorary Membership on behalf of Sir Ernest Rutherford, awarded to him "in recognition of successful researches, signally contributing to the present state of knowledge of the elements, their constitution and relationships."

This occasion also gives me an opportunity of visiting this famous Institute and of meeting some of its distinguished members.

The Franklin Medal is founded for "the recognition of those workers in physical science or technology, without regard to country, whose efforts, in the opinion of the Institute, have done most to advance a knowledge of physical science or its applications."

Only two years ago the medal was awarded to Sir Joseph Thomson, and that it should have been again awarded to another subject of King George this year is indeed a very signal honour, and one which will, I know, be appreciated not only by Sir Ernest Rutherford himself, but also by His Majesty's Government and the whole British Empire for it will demonstrate that Sir Ernest's efforts in the interests of science have been recognized by one of the great institutes of science of the world.

Sir Ernest is no doubt not a complete stranger to many of you, for I understand from him that, though born and educated in New Zealand, he spent nine years as Professor of Physics at

E. Rutherford

McGill University at Montreal, during which time he came into close contact with many scientific men in the United States of America, and he once delivered an address in Philadelphia.

He writes me that he sympathizes with me in having to speak in his place, for it is difficult to try to say what another man might have said. I will not attempt to do so, for I cannot say what he might have told us had he been here to-day, but I think it might interest you were I to read to you an extract from the Presidential Address which he delivered at the meeting at Liverpool in 1923 of the British Association for the Advancement of Science.

He said:

"In watching the rapidity of the tide of advance in physics I have become more and more impressed by the power of the scientific method of extending our knowledge of nature. Experiment, directed by the disciplined imagination either of an individual, or, still better, of a group of individuals of varied mental outlook, is able to achieve results which far transcend the imagination alone of the greatest natural philosopher. Experiment without imagination, or imagination without recourse to experiment, can accomplish little, but, for effective progress, a happy blend of these two powers is necessary. The unknown appears as a dense mist before the eyes of men. In penetrating this obscurity we cannot invoke the aid of supermen, but must depend on the combined efforts of a number of adequately trained ordinary men of scientific imagination. Each in his own special field of enquiry is enabled by the scientific method to penetrate a short distance, and his work reacts upon and influences the whole body of other workers. From time to time there arises an illuminating conception, based on accumulated knowledge, which lights up a large region and shows the connection between these individual efforts, so that a general advance follows. The attack begins anew on a wider front, and often with improved technical weapons. The conception which led to this advance often appears simple and obvious when once it has been put forward. This is a common experience, and the scientific man often feels a sense of disappointment that he himself had not foreseen a development which ultimately seems so clear and inevitable.

"The intellectual interest due to the rapid growth of science to-day cannot fail to act as a stimulus to young men to join in

scientific investigation. In every branch of science there are numerous problems of fundamental interest and importance which await solution. We may confidently predict an accelerated rate of progress of scientific discovery, beneficial to mankind certainly in a material, but possibly even more so in an intellectual, sense. In order to obtain the best results certain conditions must, however, be fulfilled. It is necessary that our universities and other specific institutions should be liberally supported so as not only to be in a position to train adequately young investigators of promise, but also to serve themselves as active centres of research. At the same time there must be a reasonable competence for those who have shown a capacity for original investigation. Not least, peace throughout the civilized world is as important for rapid scientific development as for general commercial prosperity. Indeed, science is truly international and for progress in many directions the coöperation of nations is as essential as the coöperation of individuals. Science, no less than industry, desires a stability not yet achieved in world conditions."

Mr. Chairman, it is with the greatest pleasure that I accept on behalf of Sir Ernest Rutherford this beautiful medal and this certificate which I will not fail to forward to him through the intermediary of the Foreign Office.

The President then said:

I regret very much to announce that Dr. Edward Weston is quite ill and unfortunately not able to be here, but we have with us Dr. Frank J. Sprague, of New York City, who will represent him.

Doctor Sprague said:

I regret that I am not able to speak in the befitting fashion this occasion warrants, as I am only just out of a sickbed. But I have gladly come here to join, insofar as lies in my power, in paying tribute to one of the greatest lights in the electrical field, a man whose name is a household word wherever accuracy of quantitative measurements is necessary, one who by his individual work has contributed more to the facility of carrying on the electrical industry than any other I know.

He is one of a trio of famous men of foreign birth, one of whom—a great Belgian, Doctor Baekeland—is here to-day to receive for him the honour of a distinguished award. The third,

Dr. Elihu Thomson, who came to this country from England, long ago blazoned his name upon the industry.

Doctor Weston came to this country in 1870, I think when a boy of twenty. After three years' effort by his parents to educate him in ministerial affairs, to make him a religious teacher, he changed their program and became the promoter of morals in the scientific world. In this connection he was early known for his work in the electric deposition and refining of metals, for shortly after he came here he joined the American Nickel Plating Company as its chemist. He applied himself actively to that work, and was so successful that in 1875 he established the first factory in the United States devoted entirely to the manufacture of dynamos for the electric deposition of metals.

But this was not a large enough field for a man of Weston's vision and capacity, and he shortly began the development and construction of generators for electric light, both arc and incandescent, and then the manufacture of motors for industrial purposes. I came in contact with his work very early, at the first English Electrical Exhibition, held at the Crystal Palace, Sydenham, in 1882. Only recently a graduate of the U. S. Naval Academy, I was fortunate enough to be there practically as a representative, or at least under orders, of our Navy Department. As the youngest member of the jury dealing with electrical machinery, I was, on the suggestion of Prof. Fleming Jenkins, made its secretary, probably because the older men had their many responsibilities and felt that this particular duty might be put on a younger one.

Among my associates was a representative galaxy of the leading men of the English scientific world, as for example, Prof. W. R. Adams, of the Wheatstone Laboratory, King's College, a brother of the famous Cambridge mathematician, who shared with Le Verrier the determination of the location of the planet, Neptune; Prof. Fleming Jenkins, the great electrician of Edinburgh; Capt. W. de W. Abney; Mr. Horace Darwin, brother of the naturalist, and others, all tending to kindle the enthusiasm of the visiting youngster.

So I grasped the opportunity, and soon was able to inaugurate an elaborate series of tests of gas engines, dynamos and electric lights. I clearly remember the Weston machine, an exhibit for operating incandescent lamps, particularly the fine designing which

was clearly evident and well filling the needs of the electric machine of that day.

Two years later, just forty years ago, there was held here in Philadelphia the first American Electrical Exhibition, under the auspices of this Institute. I happen to have with me the official program of that exhibition (I doubt if there are many of them in existence), and as I look at it and recall what Weston had on exhibition, I can but express astonishment at the breadth of his activities. He had dynamos all the way from ten to fifty arc lights capacity, and dynamos for incandescent lights up to 600-light capacity, and motors for many purposes, all of splendid design and performance.

In his effort to make the incandescent light an economic success, Doctor Weston ran the gamut of metallic and carbon developments, and after the adoption by Edison of the bamboo filament Weston's inventive ability, keen power of analysis and chemical knowledge made possible the curing, or making homogeneous, any irregularities of structure by the automatic deposition, at points of highest temperature, of carbon from a local dissociation of hydrocarbon gas.

Having thus attained homogeneity, by chemical means, from a non-homogeneous structure, he did not rest, but clearly saw that there must ultimately be evolved a homogeneous filament produced by chemical process, first successfully demonstrated with "Tamidine," developed from a nitro-cellulose base, a deduction which the modern ductile tungsten filament has verified in striking fashion.

Four years later Weston had accomplished perhaps as much as was to be expected, even from him, along the particular line in which he was then interested, and so he turned his attention to what was perhaps more immediately needed than anything else in the electrical world, the design and manufacture of accurate and practical electric measuring instruments for everyday laboratory and central station uses. In doing so he followed a cardinal principle of his life which has been dominant throughout his career. Our good friend, Doctor Baekeland, once said Weston had the mind and methods of research of the chemist, but that is but one example of his character. He has a passion for mathematical precision, and glories at all times in giving his thought and attention, in the creation of a machine or chemical apparatus, to

making it as near as possible perfect, the natural result of his remarkable equipment as a master mechanician.

In passing, I should call attention to kindred and necessary developments, his cadmium cell, which has practically displaced the well-known Clark cell as a standard of electromotive force, and his high resistance alloys with a minimum of temperature coefficient.

To his work he has always given the best of his life, and intelligence, and experience. A man of rather modest mien, he is at the same time rightly jealous of his particular rights, in the defense of which he has fought long and successfully. He is a charter member of the American Institute of Electrical Engineers, as well as a member of many other professional and scientific societies, and has received numerous honours and degrees, McGill University and the University of Pennsylvania having bestowed the degree of Doctor of Laws, Stevens Institute and Princeton, that of Doctor of Science; and now he is to receive that particular honour which is rightly looked upon as one of the highest awards in this country—The Franklin Medal.

I feel a keen disappointment that Edward Weston is not here to-day to receive in person this great honour, one which follows that of the Elliott Cresson Medal bestowed on him some thirteen years ago by the Institute.

At such a time I can express my thought in no better fashion than by quoting from the words of Dr. R. B. Owens, the Secretary of the Institute, on that occasion, setting forth the reasons of that award:

> "In recognition of your brilliant and successful researches in the field of electrical discovery, and also in recognition of the indomitable energy you have so lavishly and so effectively expended throughout a period of nearly half a century in the advancement of the applications of electricity to fill the needs of and supply the wants of an ever-increasingly complicated and exacting civilization."

I cannot add anything to these words, but only turn to Doctor Baekeland, one of our foremost chemists, who has been asked to receive this award for Doctor Weston, and who will express to him in behalf of this Institute an adequate appreciation of his work; and with that appreciation there will go to our absent friend all the good wishes for an early recovery to full health and a continuance for many years of his beneficent activities.

Edward Wroton.

The President, in presenting the Medal and Certificate of Honorary Membership to Doctor Baekeland, said:

I have the honour in the name of The Franklin Institute to present to you, for transmission to Doctor Weston, The Franklin Medal and a Certificate of Honorary Membership in The Franklin Institute. This award with honorary membership is made to Doctor Weston in recognition of his distinguished services to mankind rendered in the field of pure and applied science.

Doctor Baekeland, in accepting the Medal and Certificate of Honorary Membership, said:

May I be permitted to add a few words to what has been said about the work of Doctor Weston. True, enough, the physicists and electrical engineers of the world owe him great credit for his work as has been set forth by the eloquent address of Doctor Sprague. Nevertheless we chemists also feel just as much indebted to him. We are proud of him because we consider him as one of us, a chemist as well as a physicist or an engineer. This is no idle boast on our part. I know that Doctor Weston never misses an opportunity of stating that he is a chemist. We count him as one of the most distinguished members of the American Chemical Society which I have the honour to represent to-day as its President. Doctor Weston is so much a chemist that in 1915 he received the highest distinction for Industrial Chemical Research in the United States, the Sir William Perkin Medal. Physicists and electrical engineers may be interested to know that Weston, in most of his problems, introduced a chemical point of view. This was quite natural in view of the fact that he started his career as a chemist.

One of the first employments he got in New York was with a chemical concern that made photographic chemicals. This was the time of the wet-plate, when photographers made their own collodion, their own silver bath, their own paper. Whoever has gone through those delicate operations, knows the difficulties and the uncertainties caused by small variations in the composition of chemicals or in the way of using them. Photochemistry is excellent experience for any young chemist who is too much disposed to generalize all chemical reactions by simple chemical equations. Whoever has to deal with those delicate chemical phenomena which occur in the photographic image, knows that many unforeseen facts cannot be easily accounted for

by the self-satisfying but often superficial generalizations of the textbooks.

Weston's tendency to observe small details in chemical or physical phenomena led him to improve the art of nickel-plating and electrolytic deposition of metals to a point where it entered a new era. When he undertook the study of the difficulties in this art, he took nothing for granted, but, by close observation, succeeded in devising methods not only for improving the physical texture of the deposit, but for increasing enormously the speed and regularity with which the operations could be carried out; all these improvements are now embodied in the art of electrotyping, nickel-, gold-, and silver-plating.

At this time, attempts had already been made for the commercial refining of copper by means of the electric current. But this subject was then in its first clumsy period, far removed from the importance it has attained now among modern American industries. Here again, Weston brought order and method where chaos had reigned. His careful laboratory observations, harnessed by his keen reasoning intellect, established the true principles on which economic, industrial, electrolytic copper refining could be carried out. Prof. James Douglas (Commencement address, Colorado School of Mines, *Met. Chem. Eng.*, 11 (1913), 377) referred to this fact as follows: "I suppose I may claim the merit of making in this country the first electrolytic copper by the ton, but the merit is really due him (Weston) who in this and innumerable other instances has concealed his interested work for his favorite science and pursuits under a thick veil of modesty and generosity."

The whole problem of electrolytic refining, when Weston took it up, was hampered by many wrong conceptions. One of them was that a given horsepower could deposit only a maximum weight of copper, regardless of cathode or anode surface. This fallacious opinion was considered almost an axiom until Weston showed clearly the way of increasing the amount of copper deposited per electrical horsepower, by increasing the number and size of vats and their electrodes, connecting his vats in a combination of series and multiple, the only limit to this arrangement being the added interest of capital and depreciation on the increased cost of more vats and electrodes, in relation to the cost of horsepower for driving the dynamos.

The electro-deposition of metals forced Weston into the study of the construction of dynamos. Until then, the electric current used for nickel-, silver-, and gold-plating, as well as for electrotyping, was obtained from chemical batteries. Weston says that it was almost a hopeless task to wean electroplaters from these cells to which they had become tied by long experience and on the more or less skilful use of which they based many of the secrets of their trade.

If the dynamo as a cheap and reliable source of electric current was advantageous for nickel-plating, it became an absolutely indispensable factor for electrolytic copper refining. At that time, the dynamo was still at its very beginning, some sort of an electrical curiosity. It had been invented many years before by a Norwegian, Soren Hyjorth, who filed his first British patent as far back as 1855. Similar machines had been built both in Europe and America, but little or no improvement was made until Weston, in his own thorough way, undertook the careful study of the various factors relating to dynamo efficiency.

In 1876, Weston filed his first United States patent on rational dynamo construction, which was soon followed by many others, and before long, he had inaugurated such profound ameliorations in the design of dynamos, that he increased their efficiency in the most astonishing manner. The dynamos which had been constructed heretofore showed an efficiency not reaching over from 15 to 40 per cent. gross electrical efficiency, but the new dynamos constructed after Weston's principles, increased this to the unexpected efficiency of 95 per cent., and a commercial efficiency of 85 to 90 per cent. He thus marked an epoch in physical science by constructing the first industrial machine which was able to change one form of energy, motion, into another, electricity, *with a hitherto unparalleled small loss.* As the improvements in dynamos depend exclusively on physical considerations, and have little relation to the field of chemistry, I shall dispense with further discussion of this matter. But I should be permitted to point out that the first practical application of electrical power—transmission for factory purposes in this country—was utilized in Weston's factory; the success of this installation induced the Clark Thread Works, also located in Newark, to adopt for some special work this method of power transmission which has now become so universal. For this purpose, Weston had to invent

new devices for starting, and for controlling, as well as for preventing injuries to motors by overload. In Weston's factory also the electric arc was used for the first time in the United States for general illumination.

In fact, from 1875 to 1886, Weston was very energetically engaged with the development of both systems of arc and incandescent illumination by electricity. We see him start the manufacture of arc-light carbons according to methods invented by him, so that he thus became the founder of another new industry in America. He continued this branch of manufacture until 1884, at which epoch this part of the business was transferred to another company, which has made a specialty of this class of products, and developed it into a very important industry. Here, again, Weston introduced chemical methods and chemical points of view. Among the many objections which the public had against the electrical arc, was the bluish color of its light. Women especially complained that the blue-violet light did not bring out their complexions to the best advantage. Weston first tried to use shorter arcs which gave a whiter light, but this was only a partial remedy. He soon found a more radical and more complete cure by the introduction of vapors of metals or metallic salts or oxides in the arc itself, so as to modify at will the color of the light; thus he became the inventor of the so-called "flaming arc." It is noteworthy that it took about twenty years before electricians and illuminating engineers became so convinced of the advantages of the flaming arc, that it had to be "reinvented" some twenty years ago, and now it is considered the most efficient system of arc illumination.

The younger generation knows rather little about the history of the early struggles connected with the art of electrical incandescent lighting.

In his memorable work to make the electric incandescent lamp an economic possibility, we see Weston introduce over and over again chemical methods and chemical considerations. He first tried to utilize platinum and iridium, and their alloys, which he fused in a specially constructed electric furnace, devised by him, antedating the furnace described by Siemens. This is probably the first electrical furnace if you except the furnace which Hare used in his laboratory in Philadelphia.

But these platinum metals showed serious defects aside from their high cost, and by that time Weston had become so familiar with the properties of good carbon that, like other inventors, he became convinced that the ultimate success lay in that direction.

And now we see him join in that race of rivalry among inventors who all engaged their efforts in search of the really practical incandescent lamp. Among this group of men, the names of Edison here in the United States and of Swan in England have been best known. To go into the details of this struggle for improvement is entirely outside of the scope of this short review.

Edison succeeded in making incandescent lamp filaments by carbonizing selected strips of bamboo. But even a carbon made of this unusually compact and uniform material was far from being sufficiently regular and homogeneous. Indeed, all the then known forms of carbon conductors had the fatal defect of a structural lack of homogeneity. On account of this, the resistance varied at certain sections of the filament, and at these very spots the temperature rose to such an extent that it caused rapid destruction of the filament; this is somewhat similar to the chain which is just as strong as its weakest link.

These irregularities in the filament reduced enormously the term of service of any incandescent lamp. Weston tried to solve this difficulty by means of his chemical knowledge. He remembered that as a boy, when he went to visit the gas works to obtain some hard carbon for his Bunsen cell, this carbon was collected from those parts of the gas retort which had been the hottest, and where the hydrocarbon gas had undergone dissociation leaving a dense deposit of coherent carbon.

In this chemical phenomenon of dissociation at high temperature, he perceived a chemical means for "self-curing" any weak spots in the filament of his lamp. The remedy was as ingenious as simple. In preparing his filament, he passed the current through it while the filament was placed in an atmosphere of hydrocarbon gas, so that in every spot where the temperature rose highest on account of greater resistance, brought about by the irregular structure of the material, the hydrocarbon gas was dissociated and carbon was deposited automatically until the defect was cured, with the result that the filament acquired the same electric

resistance over its whole length. But this invention, however brilliant, did not limit his efforts. He had become imbued with the idea that the ideal filament would be an absolutely structureless, homogeneous filament, with exactly the same composition and the same sections throughout its whole length. He reasoned that such a filament could not be obtained from any natural products, neither from paper nor bamboo, but that it had to be produced artificially in the laboratory from an absolutely uniform, structureless chemical substance. After various unsuccessful attempts, he finally secured this result by applying his old knowledge of the days when he used to make photographic collodion. He produced a homogeneous, structureless, transparent film of nitrocellulose by evaporating a solution of this material in suitable solvents. As he could not carbonize this film on account of the well-known explosive properties of so-called "gun-cotton," he obviated this difficulty by eliminating the nitrate group of the molecule of cellulose-nitrate by means of ammonium sulphhydrate. This gave him a flexible, transparent sheet, very similar in appearance to gelatin; this material he called "Tamidine." Such films could be cut automatically with utmost exactitude, producing filaments of uniform section, which then could be submitted to carbonization, before fastening them to the inside of the glass bulb of the incandescent lamp.

It is interesting to note here that the modern tungsten lamp, in all its perfection, made of ductile tungsten, is, after all, the fullest development of the principle of an entirely structureless homogeneous chemical filament. The tungsten filament can stand much higher temperatures than carbon and this property gives it higher lighting efficiency, but the former tungsten filaments of a few years ago, which had a granular structure, had the same defect as the earlier carbon lamps, namely, a non-homogeneous texture and corresponding short life.

While Weston was wrestling with all his electrical problems, and more particularly with the construction of dynamos and motors, he was handicapped continuously by the clumsy and time-consuming methods of electrical measurements which were the best existing at that period. Up till then, these methods had been found good enough for physical laboratories, where the lack of accuracy did not result disastrously in hitting the pocket of

the manufacturer, or where abundant time, for observations and calculations, was always available. But progress in the electrical industries lagged behind the delay and uncertainties caused by electrical measurements. So Weston was compelled to invent for his own use a set of practical electrical measuring instruments. It was not long before some of his friends wanted duplicates of his instruments; before he knew it, he was giving considerable attention to the construction and further development of these instruments. Just about this time, the electric light and dynamo construction enterprises entered into a new period, where they began to develop into large unwieldy commercial organizations, requiring public franchises and which had to be backed by vast amounts of new capital. On its boards of directors, business men, or financial men and corporation lawyers, became paramount factors and eclipsed in importance the technical or scientific men, who, in earlier days, had almost exclusively contributed to the development of the art.

Following his natural inclinations, Weston soon abandoned his former business connections in order to entrench himself in a field where individuality, science and technology were of almost unique importance, and which he could develop without the necessity of incurring financial obligations beyond what he could master personally. Thus he dropped his connections with the electric-light and dynamo enterprises, and we see him now, heart and soul, in another new industry which he created—the art of making accurate, trustworthy and easy-to-use electrical measuring instruments. Did he foresee at that time that this art would attain the magnitude to which he has brought it to-day? Did he dream that his early modest shop was to develop into one of the most remarkably equipped factories in the world; an institution which seems the embodiment of what industrial enterprises may look like in future days, when scientific and liberal-minded management will have become the rule instead of the exception?

In his factory in Newark, Weston seems to have instilled some of his own reliability and accuracy in the minds of the men and women he employs.

In fact, has it occurred to you that even a man with the widest knowledge and the highest intelligence, who is not scrupulously reliable and careful, who is not the soul of honesty personified,

could not make honest and trustworthy measuring instruments nor create reliable measuring methods?

What Stas did in chemistry for atomic weights, Weston did for electrical measuring; he created radically new methods of measurement, and introduced an accuracy undreamt of heretofore. Do not forget that his problems were not easy ones. When the British Government offered a prize of $100,000 for the nearest perfect chronometer, the problem of a reliable chronometer involved considerably less difficulties and fewer disturbing factors than many of those encountered in devising and making electrical measuring instruments. But here again, even at the risk of monotonous repeating, I want to impress you with the fact that the success of the methods of Weston was found in almost every case in the application of chemical means by which he tried to solve his difficulties.

When he took up this subject, the scientists, as far back as 1884, accepted implicitly the belief that the definition of a metal and a non-metal resides in a physical distinction; that for metals the electrical resistance *increased* with temperature, while for non-metals, their resistance *decreased* with temperature. This was another one of those readily accepted axioms which nobody dared to refute or contest because they were repeated in respectable textbooks. And yet, this unfortunate behavior of metals was the greatest drawback in the construction of accurate measuring instruments. Indeed, on account of the so-called temperature coefficient, all measurements had to be corrected by calculation to the temperature at which the observation was made. This seems easy enough, but it was time-consuming and often it is more difficult to make rapid accurate observation of the temperature of the instrument itself. First of all, the thermometers are not accurate, and have to be corrected periodically, and, furthermore, it is not an easy matter to determine rapidly the temperature of a coil or an instrument. Moreover, by the very passage of the electric current, fluctuating changes in temperature are liable to occur, which would make the observations totally incorrect. All this led to hesitation and slowness in measurements. Weston wanted to correct this defect, but he was told that the very laws of physics were against his attempts. Before he was through with his work, he had to correct some of our conceptions of the laws of physics; now let us see how he did it:

Weston knew that the favorite metal for resistances was so-called German-silver. Strange to say, he was the first one to point out to the Germans themselves that "German-silver" is a word which covers a multitude of sins, and that the composition of German-silver varies considerably according to its source of supply. The result was that he soon proposed a standard copper-nickel- and zinc-alloy containing about 30 per cent. of nickel, and which had a resistance of almost twice that of ordinary German-silver and a much smaller temperature coefficient. Not satisfied with this, he took up the systematic study of a large number of alloys. The first series which he undertook to study included more than three hundred different alloys. Since that time, he has considerably increased this number, and is still busy at it. Everyone of these alloys he made himself in his laboratory, starting from pure materials, and controlling the whole operation from the making of the alloy to the drawing of wires of determined size. By long and repeated observations, in which many years have been consumed, he has been able to determine the electrical behavior of each one of these alloys at different temperatures. After awhile, he began to observe remarkable properties in some manganese alloys he compounded. He managed to produce an alloy which had sixty-five times the resistance of copper. But getting bolder and bolder, he strove to obtain an alloy which had no temperature coefficient whatever. He not only succeeded in doing this, but finally produced several alloys which had a *negative* temperature coefficient. In other terms, their resistance, instead of increasing with rise of temperature, decreased with increasing temperature. He also showed that the resistance of these alloys depends not only on their composition, but on certain treatments which they undergo, for instance, preliminary heating. And since that day, the physicists have had to bury their favorite definition of metals and non-metals.

The present generation can hardly realize what this discovery meant at that time. I could not better illustrate this than by reminding you of the fact that in 1892, at the meeting of the British Association for the Advancement of Science, where it was urged to found an institution similar to the Deutsche Reichsanstalt, Lord Kelvin said in his speech:

"The grand success of the Physikalishe Reichsanstalt may be judged to some extent here by the record put before us by Profes-

sor von Helmholtz. Such a proved success may be followed by a country like England with very great profit indeed. One thing Professor von Helmholtz did not mention was the discovery by the Anstalt of a metal whose temperature coefficient with respect to electrical resistance is practically nil, that is to say, a metal whose electrical resistance does not change with temperature. This is just the thing we have been waiting for for twenty or thirty years. It is of the greatest importance in scientific experiments, and also in connection with the measuring instruments of practical electric lighting, to have a metal whose electrical resistance does not vary with temperature; and after what has been done, what is now wanted is to find a metal of good quality and substance whose resistance shall diminish as temperature is increased. We want something to produce the opposite effect to that with which we are familiar. The resistance of carbon diminishes as temperature increases; but its behavior is not very constant. Until within the last year or so nothing different was known of metals from the fact that elevation of temperatures had the effect of increasing resistance. The Physikalische Anstalt had not been in existence two years before this valuable metal was discovered."

Then followed this colloquy:

Professor von Helmholtz: "The discovery of a metal whose resistance diminishes with temperature was made by an American engineer."

Professor Ayrton: "By an Englishman—Weston."

Lord Kelvin: "That serves but to intensify the position I wished to take, whether the discovery was made by an Anglo-American, an American Englishman, or an Englishman in America. It is not gratifying to national pride to know that these discoveries were not made in this country."

The misinformation of Kelvin was due to the fact that after the Weston patents had been published, his alloy was called "manganin" in Germany, and quite some publicity had been given to its properties with scant reference to its real inventor, an occurrence which, unfortunately, is not infrequent not only among commercial interests, but in technical or scientific circles as well.

No less important was the invention of the Weston cell, which in 1908, by the international commission for the establishment of standards of electrical measurements, became the accepted uni-

versal practical standard for electromotive force. Here again, this physical standard was obtained by chemical means.

Until Weston's researches on standard cells, the Clark cell had been the standby of the electricians and electrochemists of the world, as the standard of electromotive force. It required the keen analysis of a Weston to ascertain all the defects of this cell and to indicate the cause of them. Later, he drew from his careful chemical observations the means to construct a cell which was free from the defects of its predecessors—a cell that had no temperature coefficient and had no "lag."

He discovered that the choice of a saturated solution of sulphate of zinc in which was suspended an excess of crystals of this salt, was an unsuitable electrolyte and one of the principal causes why the indications of the Clark cell varied considerably with the temperature. It is true that this could be obviated by placing the cell in a bath of constant temperature. But this involves new difficulties due to the proper determination of the real temperature. Furthermore, there is always a "lag" in the indications due to the fact that, at varying temperatures, it requires a certain time before the solution of the salt has adjusted itself to the coefficient of saturation for each newly acquired temperature. By studying the comparative behavior of various salts at different temperatures, he came to the conclusion that cadmium sulphate is more appropriate and this was one of the several important improvements he introduced in the construction of a new standard of electromotive force.

Doctor Weston assures me that he has succeeded in making his alloys to show a change of only one-millionth for a variation of 1° C. The metallic alloys he discovered are used in practically all kinds of electrical measuring instruments throughout the world and Weston instruments and Weston methods are used as standards everywhere over the world. I have worked in several laboratories in Europe equipped with instruments said to be "just as good" as those of Weston, but in most instances they were imitations of Weston instruments and it was significant that they kept at least one Weston instrument to use to correct and compare with their national product.

The President then recognized Dr. Joseph S. Ames, who read the paper, "Early Days in Radio-activity," by Sir Ernest Rutherford (page 281).

PRESENTATION OF THE FRANKLIN MEDAL AND CERTIFICATE OF HONORARY MEMBERSHIP IN THE INSTITUTE TO SIR ERNEST RUTHERFORD AT THE FOREIGN OFFICE, JULY 14, 1924.

Letter from the Prime Minister expressing his regret at his inability to attend the ceremony.

FOREIGN OFFICE, S. W. 1.
JULY 14, 1924.

I had very much hoped, and it had been my intention, to be present at the Foreign Office to-day in order to deliver to Sir Ernest Rutherford The Franklin Medal and Certificate of Honorary Membership awarded to him by The Franklin Institute of Philadelphia. I regret to say that my Parliamentary duties have made it impossible for me to do so and my regret is all the keener since it is always a peculiar pleasure for me to take part in any ceremony which marks the close relations of friendship and mutual esteem which so happily exist between the United States of America and the British Empire. The present occasion appears to me to be a particularly happy example of the ties which bind the two countries together. It is in the field of intellectual achievement, a field which knows no international boundaries, that friendship between nations can be formed and developed and can reinforce the foundation of political friendships.

My best wishes are with Sir Ernest Rutherford on the occasion of the presentation to him of the high honour conferred upon him by an eminent scientific body of the United States.

Address of Mr. Charles Trevelyan, President of the Board of Education, representing the Prime Minister.

As you are aware, The Franklin Institute of Pennsylvania has awarded to Sir Ernest Rutherford The Franklin Medal and Certificate of Honorary Membership in recognition of successful researches signally contributing to the present state of knowledge of the elements, their constitution and relationships. I need not dilate upon the importance of the distinction conferred upon our fellow-subject by a body of the standing of The Franklin Institute; but I may perhaps remind you that this medal is awarded yearly to those workers in physical science or technology, without regard to country, whose efforts have, in the judgment of the Institute, done most to advance our knowledge of physical science or its applications. Professor Rutherford has thus this year been selected from amongst the scientists of the world as the recipient of this signal distinction.

The Franklin Institute, as most of those here present know, was founded in 1824 to meet a demand in the United States for an

Institution similar to that founded by Count Rumford in London in 1799. The founders intended it not only as a suitable memorial to the name of Franklin, but as a means of continuing for all time the work which throughout his life he probably considered as his best, namely, the discovery of physical and natural laws and their application to increase the well-being and comfort of mankind.

Sir Ernest Rutherford is peculiarly fitted to be the recipient of the Institute's medal, for he is one of the most eminent workers in the field of molecular physics and a pioneer of the modern atomic theory.

His work is too well known to you for me to speak of it in detail. It is, I think, agreed that Sir Ernest Rutherford is, beyond question, the greatest experimentalist alive now.

I cannot perhaps do better, in order to give an idea as to the character of his work, than quote the remark of a distinguished professor which has been reported to me.

"When some of your eminent men," he said, "publish an experiment, we say—'This is very interesting; we must repeat it and see whether it is true or not.' But when Rutherford publishes an experiment we say—'This is true, we need not repeat it.'"

This is the second occasion within three years on which a British man of science has been awarded this medal, for in 1922 a fellow-pioneer, with Sir Ernest Rutherford in the field of molecular physics, was awarded this medal. I refer to Sir J. J. Thomson, who received this medal at the hands of Lord Balfour at the Department of Scientific and Industrial Research, a body for which Professor Rutherford is now doing work of the highest value. I much regret that the Master of Trinity has not been able to come to-day.

The choice of Professor Rutherford for this honour gives to us of the Mother country particular pleasure, for it is an honour conferred through him upon one of His Majesty's Dominions. He is a New Zealander by birth.

I am very glad that it has been possible for the Ambassador of the United States to be present at this ceremony. We greatly value this mark of courtesy and the interest taken by Mr. Kellogg in this occasion since it is one which joins in friendly appreciation our two countries.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

PHYSICAL PROPERTIES OF MATERIALS: I. STRENGTHS AND RELATED PROPERTIES OF METALS AND WOOD.[1]

[ABSTRACT.]

THE circular represents a compilation of the most probable values, from a testing engineer's viewpoint, for the tensile, compressive, and shearing strength; ductility; modulus of elasticity; and other related properties of pure methods and their alloys, and of wood. In addition to these, and whenever the existing data warranted, the circular gives the properties of metals at elevated temperatures and their fatigue and impact properties. Values for other physical properties include those for specific gravity, melting point, and the coefficient of expansion.

Properties and uses of less commonly used metals are described briefly.

Graphical representation is used in many cases to show the effect of heat treatment, temperature, and other conditions on the properties of a material.

References to the sources are given for all values in the circular. These include the experimental results published in American and European technical periodicals, the specifications of technical societies and of government departments and unpublished results of the Bureau of Standards.

UNITED STATES GOVERNMENT SPECIFICATION FOR COAL-TAR PITCH FOR WATERPROOFING AND DAMP-PROOFING.[2]

[ABSTRACT.]

Federal Specifications Board Specification No. 83.

THIS specification was prepared by the technical committee on bituminous roofing and waterproofing materials of the Federal Specifications Board. In its preparation careful consideration was given to the suggestions received from the producers of coal-tar pitch, waterproofing contractors, architects, engineers, and large consumers of waterproofing materials, such as railroads.

* Communicated by the Director.

[1] Circular No. 101, second edition, price forty cents.

[2] Circular No. 155, price five cents.

The specification covers coal-tar pitch produced from the straight distillation of gas-house or coke-oven coal-tars or their mixtures. This coal-tar pitch is intended for use alone as a damp-proof coating for concrete, masonry, etc., or as a plying cement with Coal-tar Saturated Rag Felt for Roofing and Waterproofing (Federal Specifications Board Specification No. 81, Bureau of Standards Circular No. 156) in the construction of membrane waterproofing. It is suitable for use on tanks, retaining walls, dams, conduits, foundations of buildings, tunnels, subways, pools, reservoirs, etc., where not subject to vibration and where not exposed, except during installation, to temperatures exceeding 100° F.

The specification covers the physical characteristics of the coal-tar pitch as well as methods for sampling and testing deliveries. The physical requirements are as follows:

(*a*) *Appearance.*—The freshly melted coal-tar pitch shall have a uniform glossy black color, and on aging one week its surface shall not become dull or show any separation of oily constituents. The freshly fractured material shall present a satiny black surface.

(*b*) *Melting Point* (*Cube in Water*).—125° to 150° F.

(*c*) *Ductility at 77° F.* (*Dow Mold*), *Rate of Pull, 5 cm. per Minute.*—Minimum, 50 cm.

(*d*) *Specific Gravity at 77° F.*—1.22 to 1.34.

(*e*) *Free Carbon.*—15 to 30 per cent.

(*f*) *Distillation Test.*—Not more than 12 per cent. by weight shall distil below 572° F. The specific gravity of the distillate shall not be less than 1.03.

UNITED STATES GOVERNMENT SPECIFICATION FOR COAL-TAR SATURATED RAG FELT FOR ROOFING AND WATERPROOFING.[3]

[ABSTRACT.]

Federal Specifications Board Specification No. 81.

THIS specification was prepared by the technical committee on bituminous roofing and waterproofing materials of the Federal Specifications Board. In its preparation careful consideration was given to suggestions received from the producers of roofing and waterproofing materials, roofing and waterproofing contractors, and large users of these materials.

[3] Circular No. 156, price five cents.

The specification covers cotton-rag roofing felt impregnated with coal-tar saturating compounds. This felt is intended for use with Coal-tar Pitch for Roofing (Federal Specifications Board Specification No. 80, Bureau of Standards Circular No. 157) in the construction of 3-, 4-, and 5-ply coal-tar, built-up roofing surfaced with mineral matter, and with Coal-tar Pitch for Waterproofing and Damp-proofing (Federal Specifications Board Specification No. 83, Bureau of Standards Circular No. 155) in the construction of membrane waterproofing.

The requirements of the saturated felt are given as well as methods for the sampling and testing of deliveries. The requirements are as follows:

(*a*) *Appearance.*—The material shall be free from visible external defects and shall be uniform throughout. When unrolled at temperatures between 50° and 90° F. it shall not stick to such an extent as to cause tearing.

(*b*) *Width.*—32 or 36 inches ± one-fourth inch.

(*c*) *Gross Weight of Roll.*—50 to 80 pounds.

(*d*) *Weight of Wrapping, Packing, Etc., per Roll.*—Maximum, one-half pound.

(*e*) *Weight per 100 Square Feet, Exclusive of Packing, Etc.*—14 pounds ± 1 pound.

(*f*) *Pliability at 77° F.*—The material shall not crack on bending flat through an arc of 180° over a one-sixteenth-inch mandrel.

(*g*) *Average Breaking Strength.*—With fibre grain, 30 pounds; across fibre grain, 15 pounds.

(*h*) *Thickness of Desaturated Felt.*—Minimum, 0.025 inch.

(*i*) *Ash of Desaturated Felt.*—Maximum, 8 per cent.

(*j*) *Packing and Labelling.*—The felt shall be properly wrapped and labelled with the manufacturer's name, brand, grade, weight, area of roll, and type of saturant.

UNITED STATES GOVERNMENT SPECIFICATION FOR COAL-TAR PITCH FOR ROOFING.[1]

[ABSTRACT.]

Federal Specifications Board Specification No. 80.

THIS specification was prepared by the technical committee on bituminous roofing and waterproofing materials of the Federal Specifications Board. In its preparation careful consideration was given to the suggestions received from producers and large users

[1] Circular No. 157, price five cents.

of roofing materials, roofing contractors, architects, and engineers.

The specification covers coal-tar pitch produced from the straight distillation of gas-house or coke-oven coal-tars or their mixtures. This coal-tar pitch is intended for use as a plying cement with Coal-tar Saturated Rag Felt for Roofing and Waterproofing (Federal Specifications Board Specification No. 81, Bureau of Standards Circular No. 156) in the construction of 3-, 4-, and 5-ply built-up roofing surfaced with mineral surfacing materials conforming to Federal Specifications Board Specification No. 82, Bureau of Standards Circular No. 158 (Surfacing Materials for Bituminous Built-up Roofing). It is suitable for use on inclines not exceeding three inches to the foot on roof surfaces into which nails can be driven, and on inclines not exceeding one inch per foot on concrete.

The physical characteristics of the coal-tar pitch are given as well as methods for the sampling and testing of deliveries. The physical requirements are as follows:

(*a*) *Appearance.*—The freshly melted coal-tar pitch shall be a uniform glossy black color, and on aging one week its surface shall not become dull or show any separation of oily constituents. The freshly fractured material shall present a satiny black surface.

(*b*) *Melting Point (Cube in Water).*—140° to 150° F.

(*c*) *Ductility at 77° F. (Dow Mold), Rate of Pull, 5 cm. per Minute.*—Minimum, 50 cm.

(*d*) *Specific Gravity at 77° F.*—1.22 to 1.34.

(*e*) *Free Carbon.*—15 to 30 per cent.

(*f*) *Distillation Test.*—Not more than 12 per cent. by weight shall distil below 572° F. The specific gravity of the distillate shall be not less than 1.03.

UNITED STATES GOVERNMENT SPECIFICATION FOR SURFACING MATERIALS FOR BITUMINOUS BUILT-UP ROOFING.[5]

[ABSTRACT.]

Federal Specifications Board Specification No. 82.

THIS specification was prepared by the technical committee on bituminous roofing and waterproofing materials of the Federal Specifications Board after considering suggestions received from the producing and consuming interests involved.

It covers gravel, crushed hard blast-furnace slag, crushed stone,

[5] Circular No. 158, price five cents.

vitrified-shale promenade tile, and slate slabs for use as surfacing materials for 3-, 4-, and 5-ply built-up roofing constructed from asphalt, coal-tar pitch, and asphalt and coal-tar saturated rag felt conforming to Federal Specifications Board Specifications Nos. 80, 81, 84, and 86, respectively.

The specification gives the general requirements and gradation in size of the gravel, crushed slag, and crushed stone, and methods for their sampling and mechanical analysis. General requirements for promenade tile and slate slabs are given.

UNITED STATES GOVERNMENT SPECIFICATION FOR ASPHALT FOR MINERAL-SURFACED ROOFING.[6]

[ABSTRACT.]

Federal Specifications Board Specification No. 84.

THIS specification was prepared by the technical committee on bituminous waterproofing and roofing materials of the Federal Specifications Board. In its preparation careful consideration was given to the suggestions received from producers of asphalt, manufacturers of roofing materials, roofing contractors, and large users of asphalt built-up roofing.

The specification covers both petroleum asphalt and mixtures of refined Trinidad asphalt with petroleum or other asphaltic fluxing materials. This asphalt is intended for use with Asphalt-saturated Rag Felt for Roofing and Waterproofing (Federal Specifications Board Specification No. 86, Bureau of Standards Circular No. 161) in the construction of 3-, 4-, and 5-ply built-up roofing surfaced with mineral matter. It is adapted to inclines not exceeding three inches to the foot.

The physical characteristics of the asphalt are given as well as methods for the sampling and testing of deliveries. The general requirements of the asphalt are:

(*a*) *Appearance.*—The freshly melted asphalt shall be uniformly glossy, and on aging one week its surface shall not become dull or show any separation of oil, grease, paraffin scale, or similar material.

(*b*) *Melting Point (Ring and Ball Method).*—140° to 165° F.

[6] Circular No. 159, price five cents.

(*c*) *Penetration at 77° F. (100 g. 5 Seconds).*—25 to 50.

(*d*) *Penetration at 32° F. (200 g. 60 Seconds).*—Minimum, 10.

(*e*) *Ductility at 77° F. (Dow Mold), Rate of Pull, 5 cm. per Minute.*—Minimum, 5 cm. Other considerations being equal, preference will be given to asphalt having a minimum ductility at 77° F. of 20 cm.

(*f*) *Volatile Matter on Heating at 325° F. for Five Hours.*—Maximum, 1.5 per cent.

(*g*) *Decrease in Penetration at 77° F. after Heating as in (f).*—Maximum, 40 per cent.

(*h*) (1) *Soluble in Carbon Bisulphide* (in the case of petroleum asphalt only).—Minimum, 99 per cent.

(2) *Ash* (in the case of mixtures of refined Trinidad asphalt with petroleum asphalt or asphalt fluxing materials).—Minimum, 20 per cent. The ash shall have the characteristics of the ash obtained from refined Trinidad asphalt.

UNITED STATES GOVERNMENT SPECIFICATION FOR ASPHALT FOR WATERPROOFING AND DAMP-PROOFING.[1]

[ABSTRACT.]

Federal Specifications Board Specification No. 85.

THIS specification was prepared by the technical committee on bituminous waterproofing and roofing materials of the Federal Specifications Board. In its preparation careful consideration was given to suggestions received from the producers of asphalt, waterproofing contractors, architects, engineers, and large consumers of waterproofing materials, such as railroads.

The specification covers asphalt produced from the distillation and careful refining of asphaltic-base crude petroleums. This asphalt is intended for use alone as a damp-proof coating for concrete, masonry, etc., or as a plying cement with Asphalt-saturated Rag Felt for Roofing and Waterproofing (Federal Specifications Board Specification No. 86, Bureau of Standards Circular No. 161), in the construction of membrane waterproofing. It is suitable for use on railroad bridges, tanks, retaining walls, dams, con-

[1] Circular No. 160, price five cents.

duits, foundations for buildings, tunnels, subways, pools, reservoirs, etc.

The specification covers the physical characteristics of the asphalt as well as methods for the sampling and testing of deliveries.

The requirements of the asphalt are:

(*a*) *Appearance.*—The freshly melted asphalt shall be uniformly black and glossy, and on aging one week its surface shall not become dull or show any separation of oil, grease, paraffin scale, or similar material.

(*b*) *Melting Point (Ring and Ball Method).*—140° to 171° F.

(*c*) *Penetration at 77° F. (100 g. 5 Seconds).*—25 to 50.

(*d*) *Penetration at 32° F. (200 g. 60 Seconds).*—Minimum, 10.

(*e*) *Penetration at 115° F. (50 g. 5 Seconds).*—Maximum, 100.

(*f*) *Ductility at 77° F. (Dow Mold), Rate of Pull, 5 cm. per Minute.*—15 cm.

(*g*) *Volatile Matter on Heating at 325° F. for Five Hours.*—Maximum, 1 per cent.

(*h*) *Decrease in Penetration at 77° F. after Heating as in (g).*—Maximum, 40 per cent.

(*i*) *Soluble in Carbon Bisulphide.*—Not less than 99 per cent.

UNITED STATES GOVERNMENT SPECIFICATION FOR ASPHALT-SATURATED RAG FELT FOR ROOFING AND WATERPROOFING.[1]

[ABSTRACT.]

Federal Specifications Board Specification No. 86.

THIS specification was prepared by the technical committee on bituminous roofing and waterproofing materials of the Federal Specifications Board. In its preparation careful consideration was given to the suggestions received from the producers of roofing and waterproofing materials, roofing and waterproofing contractors, and large users of these materials.

The specification covers cotton-rag roofing felt impregnated

[1] Circular No. 161, price five cents.

with asphaltic-saturating compounds. This felt is intended for use with asphalt for mineral-surfaced roofing (Federal Specifications Board Specification No. 84, Bureau of Standards Circular No. 159) in the construction of asphalt built-up roofing and with Asphalt for Waterproofing and Damp-proofing (Federal Specifications Board Specification No. 85, Bureau of Standards Circular No. 160) in the construction of membrane waterproofing.

The requirements of the saturated felt are given as well as methods for the sampling and testing of deliveries. The general requirements are:

(*a*) *Appearance.*—The material shall be free from visible external defects and shall be uniform throughout. When unrolled at temperatures between 50° and 90° F. it shall not stick to such an extent as to cause tearing.

(*b*) *Width.*—32 or 36 inches ± one-fourth inch.

(*c*) *Gross Weight of Roll.*—50 to 80 pounds.

(*d*) *Weight of Wrapping, Packing, Etc., per Roll.*—Maximum, one-half pound.

(*e*) *Weight per 100 Square Feet, Exclusive of Packing, Etc.*—14 pounds ± 1 pound.

(*f*) *Pliability at 77° F.*—The material shall not crack on bending flat through an arc of 180° over a one-sixteenth-inch mandrel.

(*g*) *Average Breaking Strength.*—With fibre grain, 30 pounds; across fibre grain, 15 pounds.

(*h*) *Loss on Heating at 221° F. for Five Hours.*—Maximum, 4 per cent.

(*i*) *Weight per 100 Square Feet of Moisture-free Desaturated Felt.*—Minimum, 5.2 pounds.

(*j*) *Weight per 100 Square Feet of Saturant.*—Minimum, 1.4 times the weight of the moisture-free felt per 100 square feet.

(*k*) *Weight per 100 Square Feet of Comminuted Surfacing.*—Maximum, 1 pound.

(*l*) *Ash of Desaturated Felt.*—Maximum, 8 per cent.

(*m*) *Packing and Labelling.*—The felt shall be properly wrapped and labelled with the manufacturer's name, brand, grade, weight, area of roll and type of saturant.

UNITED STATES GOVERNMENT SPECIFICATION FOR ASPHALT PRIMER FOR ROOFING AND WATERPROOFING.[1]

[ABSTRACT.]

Federal Specifications Board Specification No. 87.

THIS specification was prepared by the technical committee on bituminous roofing and waterproofing materials of the Federal Specifications Board. In its preparation careful consideration was given to the suggestions received from producers and consumers of this product.

The specification covers a solution of asphalt in a volatile solvent which is intended for use in priming concrete, gypsum, and masonry surfaces over which asphalt built-up roofing and asphalt damp-proofing and membrane waterproofing are to be applied.

The specification gives the general requirements of the material and methods for the sampling and testing of deliveries. The requirements are as follows:

The material shall consist of an asphaltic base thinned to suitable brushing consistency with a volatile solvent. The asphaltic base shall be not less than 35 per cent. by weight, and when separated by appropriate methods shall have the following characteristics:

(1) *Melting Point (Ring and Ball Method).*—131° to 170° F.

(2) *Penetration at 77° F. (100 g. 5 Seconds).*—15 to 50.

The solvent used shall be a hydrocarbon distillate having an end-point on distillation not exceeding 500° F., of which not more than 20 per cent. shall distil under 248° F.

Coal Supply of Germany.—The outcome of the World War has brought about extraordinary changes with regard to possession of industrial raw materials as far as European countries are concerned and which are of greatest and far-reaching importance for Germany especially. Germany has lost practically all resources for industrial raw materials. The loss of Alsace-Lorraine is identical with the loss of iron ore mines and also German coal field reserves have greatly decreased.

A comparison of coal field reserves before and after the war of

[1] Circular No. 162, price five cents.

the various European countries as determined by the International Congress of 1913, which took place in Canada, indicates a total of 813 billion metric tons. In accordance with said estimate Germany was in 1913 the principal coal-producing country with the largest reserves, reaching 424 billion tons. England was named as second with 189 billions. Due to the war Germany lost in the first place Lorraine with an estimated coal reserve of 0.8 billion tons and the Saar district with 12.2 billion tons, a total of 13 billion tons. The loss of the coal reserves in Upper Silesia, now belonging to Poland, is estimated at 176 billion tons, so that total loss of coal reserves reaches 189 billion tons.

Russia has also suffered a loss of coal reserves due to the war, although this loss is insignificant compared with Germany's. By the separation of Poland from Russia, the latter lost a coal reserve of 3 billion tons which total does not alter much Russia's importance as coal producer. Therefore, France and Poland solely have gained by the alteration of the map of Europe. Coal reserves of France have increased from 18 to 31 billion tons and those of Poland from practically nothing to 208 billions.

Since January 1st, when France occupied the Ruhr, Germany does not figure any more among the leading coal-producing countries of Europe. Considering that France to-day controls the coal fields in the Ruhr and those on the left side of the Rhine German coal reserves as estimated above with 235 billion tons are reduced by 90 per cent. of the Ruhr reserves of 190 billion tons and by 13 billions of the reserves on the left side of the Rhine. Therefore Germany, formerly the largest coal producer in Europe, is now fourth. Germany's place is taken by France and Poland while England has been placed third on the list.

Germany's remaining coal reserves of 64 billion tons are divided as follows: Upper Silesia, 35 billion tons; Westphalia, 19 billions; Lower Silesia, 3 billions, and Saxon coal fields, 1 billion. In addition there are 6 billion tons of lignite in Central Germany. (*From Publication of the American Chamber of Commerce in Germany.*)

H. L.

Qualitative Test for Acetone.—Frommer, in 1905, described a delicate test for acetone depending on the reaction with salicyl aldehyde in presence of a strongly alkaline solution. LEFFMANN (*Amer. Jour. Pharm.*, 1924, **96**, 507) finds that vanillin may be used instead of the salicyl aldehyde, which is not a familiar laboratory reagent. The test is performed by adding a few c.c. of a 5 per cent. solution of vanillin in dilute alcohol to about 10 c.c. of the sample, and then dropping in a small piece of sodium hydroxide. A red ring soon forms just above the alkaline layer, if an appreciable amount of acetone is present. Cumarin gives no reaction. A. R.

NOTES FROM THE RESEARCH LABORATORY, EASTMAN KODAK COMPANY.*

THE MEASUREMENT OF INTENSIFYING FACTORS OF X-RAY INTENSIFYING SCREENS.[1]

By R. B. Wilsey.

HERETOFORE, the sensitometric determinations of X-ray intensifying screen factors have not given reliable results owing to the fact that the intensity of the fluorescent light depends considerably on the quality and intensity of the incident X-rays, and the proper conditions for exposure of the screens had not been determined. In the present experiment it was found that satisfactory values of intensifying factors were obtained if the X-rays were filtered by a sufficient thickness of aluminum to give the same intensity and quality of the X-rays as is transmitted by a 15-cm. thickness of water under the standard conditions of X-ray tube operation; a correction factor must be applied to take account of the difference in the sensitivity of the screens to direct and scattered radiation.

The exposure conditions determined upon were as follows: 60 kilovolts on the X-ray tube; 4 milliamperes; 1 cm. aluminum filter; and 50 cm. target film distance; the ratio of the exposure with and without screens for a density of one by standard development must be multiplied by 0.83 for single screens and 0.78 for double screens to obtain the correct intensifying factor.

Cassettes were tested for contact between film and screen by the use of a screen ruled with cross-lines; cassettes with rigid back lined with thin felt gave poor contact in central area, owing to the bulge in the face of the cassette. The back of a cassette should be slightly flexible and should be lined with thick soft felt.

SLOW GELATION IN PRESSURE-STILL TAR.[2]

By S. E. Sheppard and L. W. Eberlin.

A QUANTITY of a petroleum residue, so-called " pressure-still " tar, or oil, was obtained from Burton stills, for experimental work on colloidal fuel. It was desired to find a process that would

* Communicated by the Director.

[1] Communication No. 201 from the Research Laboratory of the Eastman Kodak Company and published in *Radiology*, **2**, 311–15 (1924).

[2] Communication No. 204 from the Research Laboratory of the Eastman Kodak Company and published in *Ind. Eng. Chem.*, **16**: 832, 1924.

prevent flocculation and settling, and that would arrest or delay the slow gelation of the pressure-still tar. Two methods were investigated. By the first method, in which naphthalene was added to the sample, it was possible to reduce the viscosity and to remove 50 per cent. of the free carbon by centrifugation. The treatment with naphthalene improved the material as a fuel oil, but soon reached a point at which it became uneconomical. The second method used was to treat the oil with a "fixateur." It was found that the samples containing the fixateur showed less gelation than the straight tar which contained no fixateur. Samples that had been standing for three years showed pronounced gelation.

Allotropy of Germanium Dioxide.—HORACE BLANK (PH.D. Thesis, Graduate School, University of Pennsylvania, 1924, 28 pages) has prepared an insoluble form of germanium dioxide. A soluble form of this dioxide is obtained by hydrolysis of germanium tetrachloride. If its solution be evaporated, an anisotropic residue of germanium dioxide is obtained, which is soluble in water, but is partially converted into a water-insoluble modification on heating at temperatures between 225° and 1040° C. In a given period of time, the maximum yield of the insoluble variety occurs at a temperature of 380° C. All forms of germanium dioxide fuse at a temperature of approximately 1100° C. to a viscous liquid; the latter solidifies to a glass which is soluble in water.

Germanium dioxide apparently exists in three allotropic modifications. The insoluble form may be considered as stable at ordinary temperatures. In addition to this stable form, two metastable forms exist; both are soluble in water; they differ from each other with respect to the rate at which they are transformed into the insoluble form. J. S. H.

The Vacuum—There's Something in It.—This was the title of the public lecture delivered at the last annual convention of the Society of the Sigma Xi by W. R. WHITNEY (*Sigma Xi Quarterly*, 1924, **12**, 31–38). The vacuum has an endless amount of interest and utility. Each week, the American public now purchases over a million dollars' worth of glass vacua. The most perfect vacuum yet obtained probably contains as many molecules of gas per cubic inch as there are people in the entire world. The applications of the vacuum are most varied, ranging from the vacuum-jacketed bottle, the incandescent bulb, and the X-ray tube to the transformation of currents, the determination of the internal structure of crystals and of chemical elements, and wireless communication. J. S. H.

NOTES FROM THE U. S. BUREAU OF CHEMISTRY.*

RELATION BETWEEN THE COMPOSITION OF CALIFORNIA CANTALOUPES AND THEIR COMMERCIAL MATURITY.[1]

By E. M. Chace, C. G. Church, and F. E. Denny.

[ABSTRACT.]

THE soluble solids content, the refractive index, and the sucrose content of the juice of cantaloupes increase and the percentage of starch in the seeds decreases as the melons ripen.

The juice of melons which are mature when picked has a specific gravity of at least 1.040, equivalent to 10 per cent. solids, a refractive index of at least 55 on the immersion refractometer, and a sucrose content not less than 4.5 per cent. The seeds of such melons contain less than 0.5 per cent. of starch.

Melons gain in flavor, but not in sweetness, after being picked. On storage at low temperatures, such as are found in iced cars, the melons change but little, so that their composition during and immediately after storage indicates their condition when picked. After softening, if kept at ordinary temperatures there is a slight loss in sucrose. After picking and storage, there is a loss of starch in the seeds.

MAKING VINEGAR IN THE HOME AND ON THE FARM.[2]

By Edwin LeFevre.

[ABSTRACT.]

VINEGAR can be made from any fruit, or, in fact, from any material which contains enough sugar and is in no way objectionable.

Whether it is done on a small scale in the home, on a larger scale on the farm, or on a still larger scale in the factory, the production of vinegar is the result of two distinct fermentation processes—an alcoholic fermentation followed by an acetic fermentation.

Farmers' Bulletin 1424 gives methods by which vinegar of

* Communicated by the Chief of the Bureau.

[1] Issued as U. S. Department of Agriculture Bulletin No. 1250.

[2] Issued as U. S. Department of Agriculture Farmers' Bulletin 1424.

good quality may readily be made from apples, peaches, grapes, and other fruits, large quantities of which are wasted each year in the United States.

INHERITANCE OF COMPOSITION IN FRUIT THROUGH VEGETATIVE PROPAGATION.[3]

BUD VARIANTS OF EUREKA AND LISBON LEMONS.

By E. M. Chace, C. G. Church, and F. E. Denny.

[ABSTRACT.]

AN investigation was conducted to determine the extent to which fruit from different Eureka and Lisbon lemon trees varies in composition, whether or not this variation is greater between different strains of trees than between individual trees, and whether or not the peculiarities of composition found in the fruit of parent trees are transmitted to the fruit of progeny trees by vegetative propagation.

The following probable differences were found to exist:

In the Lisbon variety, the Dense Unproductive strain has a higher specific gravity than the Bull strain. The Bull strain has the highest proportion of rind found in any of the strains of this variety. The Lisbon strain is more highly acid than either the Open or the Dense Unproductive strain. The Dense Unproductive strain is also more acid than the Open strain.

In the Eureka variety, the Eureka strain is more acid than the Shade Tree strain. Other differences may exist, but the data at hand are inconclusive in these cases.

Prevention of Lead Poisoning in the Rubber Industry.—In the manufacture of rubber products, compounds of lead, such as litharge, are used as accelerators in the process of vulcanization. Oils or petrolatum are added in order to influence the texture of the final product, and are known as softeners. LEONARD GREENBURG (*Public Health Reports*, 1924, **39**, 1567–1568) recommends that the litharge and the softener be mixed in the usual ratio (8 parts of the former to 1 part of the latter), and that the requisite amount of this salve-like mixture be added to each batch prior to vulcanization. By this procedure, the danger to the workmen from toxic lead dust is kept at a minimum. J. S. H.

[3] Issued as U. S. Department of Agriculture Bulletin No. 1255.

Detection of Diethyphthalate.—The use of this substance for denaturing alcohol intended for external use, and the liability of such alcohol to be deprived of most of the ester (which is extremely bitter) in order to make a beverage, has rendered delicate tests for it of much value in tracing such recoveries. LEFFMANN (*Amer. Jour. Pharm.*, 1924, **96**, 503) has made comparative examinations of several of the tests lately suggested. These depend upon the power of the phthalates to react with phenolic substances, producing highly colored compounds. Lyons first suggested resorcinol, producing fluorescein. Calvert found it possible to obtain phenolphthalein. Andrew found that the resorcinol method is unsafe unless a low temperature is used. Utz published in a German journal recently a procedure with resorcinol which is very delicate; but Leffmann found it liable to give fluorescent solutions when no phthalate is present. His comparisons lead to approval of Andrew's process, as published in *J.I.E.C.* (1923, 15, 838). A. R.

Zinc Hypochlorite.—J. A. W. LUCK (*Jour. Am. Pharm. Asso.*, 1924, **13**, 710–712) has attempted to prepare this compound by the action of chlorine gas on a fine suspension of zinc oxide in water. A solid product deposited which contained 16.4 per cent. of available chlorine when dried for a period of forty-eight hours at a temperature of 40° to 60° C. When the hydroxyl ion concentration of the suspension was increased by addition of sodium hydroxide, the dried product contained 17.96 per cent. available chlorine. The moist product contained as much as 29.98 per cent. available chlorine calculated on the dry basis. In other words, available chlorine was lost during drying. Luck calculates that, with this maximum content of available chlorine, 72.96 per cent. of the solid matter in the moist product consisted of a mixed salt of zinc with the formula Zn.OCl.Cl. Pure zinc hypochlorite would be a valuable therapeutic agent, since it would contain both the zinc cation with its astringent property and the hypochlorite anion (OCl) with its oxidizing and antiseptic properties. J. S. H.

Abrasive Materials in 1923.—The production of natural abrasive materials in 1923 was much larger than in 1922, according to a statement issued by the Department of the Interior, prepared in the Geological Survey. The total quantity produced was about 250,000 tons, valued at more than $4,000,000. In addition there was produced in 1923 more than 80,000 tons of artificial abrasives, valued at $8,778,000.

Atomic Weight of Zirconium.—F. P. VENABLE and J. M. BELL, of the University of North Carolina (*Jour. Am. Chem. Soc.*, 1924, **46**, 1833–1834), have recalculated the results obtained in their research on the atomic weight of zirconium, and find that the atomic weight of this element is very close to 91.2. J. S. H.

THE FRANKLIN INSTITUTE.

To the Members of The Franklin Institute:

In connection with the Centenary Celebration of The Franklin Institute, the following program is issued, based on information available September 4, 1924.

Formal invitations have been extended to universities and colleges, learned and professional societies, and to certain industrial institutions, which have been closely affiliated with the Institute, with the request that they appoint delegates to represent them on this occasion.

No formal invitations have been issued to individuals, but cards have been printed on which is extended a cordial invitation to the recipient to attend the various lectures incident to the Celebration.

I shall be glad to have members send me the names and addresses of individuals to whom they desire these cards sent.

It is hoped that all members of the Institute will arrange to attend some or all of these functions.

In order to provide ample accommodation for the audiences, it has been found necessary to avail ourselves of the courteous offer of the University of Pennsylvania and many of the addresses scheduled will be delivered in the various lecture halls of the University.

Wm. C. L. Eglin,
President.

CENTENARY CELEBRATION OF THE FOUNDING OF THE FRANKLIN INSTITUTE AND THE INAUGURATION EXERCISES OF THE BARTOL RESEARCH FOUNDATION.

September 17, 18, 19, 1924, Philadelphia.

THE COMMITTEES OF THE CENTENARY CELEBRATION.

HONORARY COMMITTEE.

ELIHU THOMSON, *Chairman*

NICHOLAS F. BRADY	JOSIAH H. PENNIMAN
WALTON CLARK	JOHN J. PERSHING
MORRIS L. CLOTHIER	J. HOWARD PEW
CHARLES A. COFFIN	SAMUEL REA
PIERRE S. DUPONT	THEODORE W. RICHARDS
THOMAS A. EDISON	WILLIAM CAMERON SPROUL
SAMUEL INSULL	HARRY B. THAYER
JOSEPH B. MCCALL	SAMUEL M. VAUCLAIN
RANDAL MORGAN	RODMAN WANAMAKER
WILLIAM H. NICHOLS	EDWARD WESTON

EXECUTIVE COMMITTEE.

WM. C. L. EGLIN

WALTON CLARK — C. C. TUTWILER

HENRY HOWSON, *Treasurer*

GELLERT ALLEMAN, *Chairman*

PROGRAM.

WEDNESDAY, SEPTEMBER 17TH.

9.00 A.M. Assembly of Delegates and Guests at the Hall of The Franklin Institute, 15 South Seventh Street.

9.45 A.M. Academic Procession from the Hall of The Franklin Institute to the Walnut Street Theatre. Academic Costume is in order, but not required.

10.15 A.M. Invocation. Reverend Louis C. Washburn, S.T.D., Rector of Christ Church, Philadelphia.

10.30 A.M. Address of Welcome. The Honorable W. Freeland Kendrick, Mayor of Philadelphia. Address: President Wm. C. L. Eglin, Sc.D.

Address: Professor Elihu Thomson, Ph.D., Sc.D., Honorary Chairman of the Centenary Celebration Committee of The Franklin Institute.

1.00 P.M. Luncheon to Delegates and Guests, the Bellevue-Stratford.

2.30 P.M. Sectional Meetings, The Franklin Institute, 15 South Seventh Street, the University of Pennsylvania.

7.30 P.M. Dinner Parties.

THURSDAY, SEPTEMBER 18TH.

10.00 A.M. Sectional Meetings, the University of Pennsylvania.

1.30 P.M. Luncheon to Delegates and Guests, the Bellevue-Stratford.

2.30 P.M. to 6.00 P.M. Garden Party.

8.30 P.M. Open Meeting, the University Museum, Thirty-third and Spruce Streets. President Wm. C. L. Eglin, Sc.D., presiding, will introduce the Chairman of the evening, The Hon. William Cameron Sproul, LL.D. Address: "The Natural and Artificial Disintegration of Elements," by Professor Sir Ernest Rutherford, Kt., D.Sc., LL.D., Ph.D., D.Phys., F.R.S., Trinity Collge, Cambridge.

FRIDAY, SEPTEMBER 19TH.

9.30 A.M. Unveiling of Tablet at Bartol Research Foundation, 127 North Nineteenth Street, Mr. C. C. Tutwiler, presiding.

9.45 A.M. The Academy of Natural Sciences, Nineteenth and Race Streets. Address: "The Fifth Estate," by Arthur D. Little, Chem.D., Cambridge. Address: "Stimulation of Research and Invention," by Professor D. S. Jacobus, Dr. Eng., New York City.

11.30 A.M. Sectional Meetings, the University of Pennsylvania.

2.00 P.M. Luncheon to Delegates and Guests, the Bellevue-Stratford.

4.00 P.M. Convocation at the University of Pennsylvania, President Josiah Harmer Penniman, Ph.D., LL.D., L.H.D., presiding.

7.30 P.M. Banquet to Delegates and Guests, the Bellevue-Stratford.

Presentation of greetings from universities, colleges, learned and professional societies and industrial organizations.

SECTIONAL MEETINGS.

WEDNESDAY, SEPTEMBER 17TH.

2.30 P.M.—The Hall of The Franklin Institute, 15 South Seventh Street. Rear Admiral W. A. Moffett, presiding.

Professor Joseph S. Ames, Ph.D., LL.D., The Johns Hopkins University, "Recent Developments in Aeronautics."

Major General Mason M. Patrick, Chief, United States Air Service, "Military Aircraft and Their Use in Warfare."

Major General George Owen Squier, Ph.D., United States War Department, "Electrical Communications for Military Purposes."

General John J. Carty, D.Sc., LL.D., American Telephone and Telegraph Company, "Progress in Telephony."

2.30 P.M.—Lecture Room No. 216, Engineering Building, University of Pennsylvania. Dean Howard McClenahan, presiding.

Professor W. Lash Miller, Ph.D., University of Toronto, "Concentration and Polarization at the Cathode during Electrolysis of Solutions of Copper Salts."

Professor Julius Stieglitz, Ph.D., D.Sc., Ch.D., University of Chicago, "The Theory of Color Production in Organic and Inorganic Compounds."

Professor E. G. Coker, M.A., D.Sc., F.R.S., University College, London, "Photo-elasticity."

2.30 P.M.—Lecture Room No. 226, Engineering Building, University of Pennsylvania. President Frank J. Sprague, presiding.

Dean Dexter S. Kimball, M.E., The College of Engineering, Cornell University, "The Progress and Promise of Engineering."

Daniel E. Moran, M.Sc., Consulting Engineer, "Some of the Effects of Loading Granular Material."

Brigadier General Edgar Jadwin, United States War Department, "Modern Military Engineering."

2.30 P.M.—Lecture Room No. 314, Engineering Building, University of Pennsylvania. Director Arthur L. Day, presiding.

Professor W. J. Humphreys, C.E., Ph.D., United States Weather Bureau, "The Way of the Wind."

William D. Coolidge, Ph.D., General Electric Company, "Modern X-ray Tube Development."

Professor William Lawrence Bragg, M.A., F.R.S., Victoria University, "Inorganic Crystals."

SECTIONAL MEETINGS.

THURSDAY, SEPTEMBER 18TH.

10.00 A.M.—Harrison Chemical Laboratory, University of Pennsylvania. Doctor Willis R. Whitney, presiding.

Professor F. Haber, Ph.D., Direktor, Institut für Physikalische Chemie und Elektrochemie, "Technical Results of the Theoretical Development in Chemistry."

Irving Langmuir, Ph.D., D.Sc., LL.D., General Electric Company, "Electric Discharges in Gases at Low Pressures."

Professor Wilder D. Bancroft, Ph.D., Cornell University, "The Development of Colloid Chemistry."

Director C. E. K. Mees, D.Sc., Eastman Kodak Company, "Applied and Scientific Photography."

10.00 A.M.—Lecture Room No. 214, Engineering Building, University of Pennsylvania. General Guy E. Tripp, presiding.

Professor P. W. Bridgman, Ph.D., Harvard University, "Some Aspects of High Pressure Research."

Professor Dayton C. Miller, Sc.D., Case School of Applied Science, "The Phonodeik."

Professor Charles E. Mendenhall, Ph.D., The University of Wisconsin, "Electronic Phenomena at the Surface of Metals."

Professor Sir William Henry Bragg, K.B.E., M.A., D.Sc., F.R.S., Royal Institution, "The Carbon Atom in Crystalline Structure."

10.00 A.M.—Lecture Room No. 216, Engineering Building, University of Pennsylvania. Professor Augustus Trowbridge, presiding.

Director Arthur L. Day, Ph.D., Sc.D., Geophysical Laboratory, Carnegie Institution, "Some Causes of Volcanic Activity."

Professor Charles Fabry, University of Paris, "Spectroscopy in Past and Present."

Professor Augustus Trowbridge, Ph.D., Princeton University, "Infra-red Spectroscopy."

F. W. Peek, General Electric Company, "Lightning."

Professor A. E. Kennelly, Sc.D., Harvard University and Massachusetts Institute of Technology, "The Measurement of Acoustic Impedance by the Aid of the Telephone Receiver."

10.00 A.M.—University of Pennsylvania Museum. Dr. Samuel Insull, presiding.

E. W. Rice, Jr., Sc.D., D.Eng., Honorary Chairman, General Electric Company, "The Field of Research in Industrial Institutions."

Ralph Modjeski, Dr.Engr., Consulting Engineer, "Unusual Problems Encountered in the Design and Construction of Large Bridges."

Sir Charles Algernon Parsons, K.C.B., M.A., LL.D., D.Sc., F.R.S., Newcastle-on-Tyne, "Steam Turbines on Land and Sea."

William LeRoy Emmet, Sc.D., General Electric Company, "Mercury Boiler."

FRIDAY, SEPTEMBER 19TH.

11.30 A.M.—Harrison Chemical Laboratory, University of Pennsylvania. Professor Joseph S. Ames, presiding.

Professor Pieter Zeeman, Ph.D., Sc.D., University of Amsterdam, "Radiating Atoms in Magnetic Fields."

Professor John Sealy Edward Townsend, F.R.S., University of Oxford, "Motion of Electrons in Gases."

Professor W. F. G. Swann, D.Sc., University of Chicago, "The Origin of the Earth's Electric and Magnetic Phenomena."

J. Slepian, M.A., Ph.D., The Westinghouse Electric and Manufacturing Company, "Electric Discharges Between High Resistance Electrodes."

11.30 A.M.—Lecture Room No. 216, Engineering Building, University of Pennsylvania. Doctor Arthur D. Little, presiding.

Director Charles L. Reese, Ph.D., Sc.D., E. I. du Pont de Nemours and Company, "Twenty-five Years' Progress in Explosives."

Professor F. G. Donnan, C.B.E., M.A., Ph.D., D.Sc., F.I.C., F.R.S, University College, London, "The Influence of J. Willard Gibbs on the Science of Physical Chemistry."

Provost Emeritus Edgar F. Smith, Ph.D., LL.D., L.H.D., Chem.D., Litt.D., M.D., University of Pennsylvania, "Early Science in Philadelphia."

11.30 A.M.—Lecture Room No. 226, Engineering Building, University of Pennsylvania. Professor A. E. Outerbridge, presiding.

Professor C. H. Mathewson, Ph.D., Yale University, "The Trend in Physical Metallurgy."

George L. Kelley, Ph.D., Philadelphia, "The Restraint of Exaggerated Grain Growth in Critically Strained Metals."

Professor Bradley Stoughton, Lehigh University, "Magnetic Analysis of Steel."

T. D. Yenson, E.E., The Westinghouse Electric and Manufacturing Company, "Magnetic Properties of Fifty Per Cent. Iron, Fifty Per Cent. Nickel Alloys."

11.30 A.M.—Lecture Room No. 314, Engineering Building, University of Pennsylvania. Major General George O. Squier, presiding.

Dean Harold Pender, Ph.D., Moore School of Electrical Engineering, University of Pennsylvania, "A New Type of Non-inductive High Resistance."

Professor A. A. Michelson, Ph.D., Sc.D., LL.D., The University of Chicago, "Velocity of Light."

Major General C. C. Williams, United States War Department, "Modern Ordnance."

THE REPRESENTATIVES FROM UNIVERSITIES AND COLLEGES IN THE ORDER OF ESTABLISHMENT.

Université de Paris a la Sorbonne
Professor Charles Fabry
Professor Henri Abraham
University of Oxford
Professor John Sealy Edward Townsend, F.R.S.
University of St. Andrews
Principal and Vice-chancellor James Calquhoun Irvine, C.B.E., D.Sc., LL.D., F.R.S.
William J. Matheson, LL.D.
Université de Louvain
Professor C. J. de la Vallee Poussin
University of Glasgow
Professor G. W. Howe, D.Sc.
Albertus Universität (Königsberg)
Professor Albert Kraus, J. D.
Professor Walter Benthin, M.D.
University of Cambridge
Sir Ernest Rutherford, Kt., D.Sc., LL.D., Ph.D., D.Phys., F.R.S.
Trinity College (Dublin)
Mr. Charles Frederick Draper, M.A., B.A.I., O.B.E.
University of Amsterdam
Professor Pieter Zeeman, Ph.D., Sc.D.
Harvard University
Professor Hector James Hughes
College of William and Mary
Robert S. Bright, Esq.
Yale University
James H. Penniman, Litt.D.
Washington College
President Paul E. Titsworth, Ph.D.
University of Pennsylvania
President and Provost Josiah Harmer Penniman, Ph.D., LL.D., L.H.D.
Vice-provost James Hartley Merrick, Sc.D.
Princeton University
Dean Arthur M. Greene, Jr., M.E., D.Sc., D.Eng.
Columbia University
Professor George B. Pegram, D.Sc., Ph.D.
Professor Michael I. Pupin, Ph.D., Sc.D., LL.D.
Brown University
Superintendent Edwin C. Broome, Ph.D.
Rutgers College
Professor George Winchester, Ph.D.
College of Physicians of Philadelphia
Thomas R. Neilson, M.D.
University of New Zealand
Professor Albert R. Acheson
University of Vermont
Captain Leonard S. Doten
Williams College
Mr. Quincy Bent

Washington and Jefferson College
The Reverend E. E. Robb, D.D.
University of Maryland
Dean Arthur Newhall Johnson
Hamilton College
Professor Joshua E. Sweet, M.D., Sc.D.
Colgate University
Professor Harry T. Collings, Ph.D.
Amherst College
Professor Herman V. Ames, Ph.D.
George Washington University
President William Mather Lewis
McGill University
Professor A. S. Eve, C.B.E., D.Sc., F.R.S.
Philadelphia College of Pharmacy
Professor Charles LaWall, Phar.D., Sc.D.
Trinity College (Hartford)
Professor Henry Augustus Perkins, Sc.D.
Rensselaer Polytechnic Institute
Strickland L. Kneass, C.E.
The Agnes Scott College
Professor Emily E. Howson, M.A.
University of Toronto
Professor W. Lash Miller, Ph.D.
Ohio Mechanics Institute
President John T. Faig
University of the State of New York
Professor John M. Clarke, Ph.D., LL.D., Sc.D.
Technische Hochschule, Hanover
Herr Rektor E. Vetterlein
Lafayette College
Colonel Horace C. Booz
Georgia School of Technology
President Marion L. Brittain, LL.D.
Oberlin College
Professor Leon Alonzo Ryan, Ph.D.
University of Delaware
President Walter Hullihen, Ph.D.
Tulane University of Louisiana
Mr. R. E. Brunswick Sharp
Marietta College
Professor Howard H. Mitchell, Ph.D.

Alfred University
Doctor Walter G. Karr
Mount Holyoke College
Professor Emma P. Carr, Ph.D.
University of Michigan
Dean Mortimer E. Cooley, LL.D., Eng.D., Sc.D.
University of Missouri
Mr. Earl B. Smith
Fordham University
Professor Carl P. Sherwin, M.D., Sc.D., LL.D.
University of Notre Dame
Mr. John Henry Neeson
University of Sydney
Mr. V. J. F. Brain
College of Technology
Professor W. L. Bragg, O.B.E., M.A., F.R.S.
University of Manchester
Professor W. L. Bragg, O.B.E., M.A., F.R.S.
University of Utah
Leon L. Watters, Ph.D.
Imperial College of Science and Technology
Professor Sir Thomas Holland, K.C.S.I., K.C.I.E., D.Sc., LL.D., F.R.S.
Tufts College
Tabor Ashton, M.A.
University of Melbourne
Professor W. L. Bragg, O.B.E., M.A., F.R.S.
Elmira College
President Frederick Lent, D.D., Ph.D., LL.D.
Pennsylvania State College
Dean R. L. Sacket, C.E.
University of Calcutta
Professor C. V. Raman, D.Sc., F.R.S.
University of Madras
The Reverend W. I. Chamberlain, D.D., Ph.D.
Wheaton College
Mrs. Mercer Brown Tate

Massachusetts Institute of Technology
Professor A. E. Kennelly, Sc.D.
Northwestern University
Professor Herbert W. Hess, Ph.D.
University of Washington
Professor Thomas Gordon Thompson, Ph.D.
Vassar College
Professor Edna Carter, Ph.D.
Robert College
Professor Lynn A. Scipio, M.E.
Swarthmore College
President Frank Aydelotte, LL.D.
University of Denver
Professor N. B. Heller, Ph.D.
Cornell University
Professor Wilder D. Bancroft, Ph.D., Sc.D.
Dean Dexter S. Kimball, M.E.
Worcester Polytechnic Institute
President Ira N. Hollis, Sc.D., L.H.D.
Lehigh University
Professor Bradley Stoughton
University of California
Frederick Gardner Cottrell, Ph.D.
Purdue University
Julius William Sturmer, Phar.D.
Ursinus College
President George L. Omwake, LL.D.
Professor Matthew Boardwood, M.D., Sc.D.
Clark University
President Wallace W. Atwood, Ph.D.
Syracuse University
Mr. Everett S. Elwood
University of Nebraska
The Reverend David D. Forsyth, D.D.
Smith College
Professor Frank Allan Waterman, Ph.D.
University of Adelaide
Mr. R. C. Robin
University of Nevada
Honorable James Fred Abel, M.A.
The Johns Hopkins University
Professor Joseph S. Ames, Ph.D., LL.D.
University of Oregon
Mr. F. T. Struck
Bryn Mawr College
President Marion Edwards Park, Ph.D.
Professor James Barnes, Ph.D.
College of Science for Ireland
Mr. P. Cormack, F.C.Sc.I.
Case School of Applied Science
President Charles S. Howe, Ph.D., Sc.D., LL.D.
South Dakota State College
Doctor Lindsay Whitehead
University of Liverpool
Professor E. C. C. Baly, C.B.E., F.R.S.
University of the Panjab
The Reverend Sir James Ewing, K.C.B., LL.D., D.Sc., Litt.D., F.R.S.
Temple University
The Reverend Dean James H. Dunham, LL.D., Ph.D.
Stanford University
Professor David Locke Webster, Ph.D.
Catholic University of America
The Right Reverend Thomas J. Shahan, S.T.D., J.U.L.
University of Allahabad
Professor Winfield Dudgeon, Ph.D.
Drexel Institute
President Kenneth G. Matheson, LL.D., Sc.D.
University of Chicago
Professor Albert A. Michelson, Sc.D., LL.D.
Lewis Institute
Dean John Derck Nies
University of Montana
Professor N. J. Lennes, Ph.D.
Clarkson College of Technology
Mr. Howard S. Phelps
Haute École technique de Bohème
Professor Doctor Vladimir Novak

Carnegie Institute of Technology
President Thomas Stockham Baker, Ph.D.
Rhodes University College
Doctor G. S. Cogan
University of Leeds
H. D. Dakin, D.Sc., F.R.S.
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Separation of Molybdenum from Tungsten.—OTTO FOLIN and HARRY TRIMBLE, of Harvard University (*Jour. Biol. Chem.*, 1924, 60, 473–479), find that molybdenum can be practically completely separated from tungsten by percipitation of the molybdenum as its sulphide by the action of hydrogen sulphide in the presence of approximately 27 per cent. of orthophosphoric acid. This separation is of great service in the preparation of phosphotungstic acid free from phosphomolybdic acid. J. S. H.

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BOOK REVIEWS.

THE STRUCTURE OF CRYSTALS. By Ralph W. G. Wyckoff. 462 pages, 213 illustrations, 8vo. The Chemical Catalog Company, Inc., New York, 1924. Price, $6.

This is one of the series of monographs issued under the auspices of the American Chemical Society, a series that has now reached an imposing list of works on many departments of chemistry, pure and applied. While, as might be expected, the applied fields, especially in the greater industries, have received principal attention, theoretical questions have been given a large share.

The present book relates to one of the most recent and most abstruse departments of physical chemistry. As the author remarks in the preface, the field to which the book is devoted is avoided by many chemists and physicists, each regarding the subject as rather belonging to the province of the other. The methods of investigation are so definitely physical, that the chemist turns away from them. Many physicists are not inclined to regard physical processes alone as insufficient, and it must be admitted that so far as this country is concerned, crystallography has not been extensively cultivated, except by mineralogists. Mineralogists, of course, have for many years laid great stress on crystal forms and have developed to a high degree the mathematical principles concerning such forms. Yet it is not likely that many of them would care to pursue deeply the line of exposition presented by this book, and we may agree with the author that among the older sciences, the new science of crystal structure is largely ignored.

Research, ingenious and patient, has developed an immense amount of important and novel data, which are collected in this volume and set forth with an abundance of explanation and illustration. Wyckoff finds that the greatest difficulty in crystal analysis is to think in three dimensions. To aid in such conception, and to keep the book within the compass of the chemical aspect, the text has been replaced by abundant diagrams. To provide for the somewhat variable training of those who will use the book, considerable information is given concerning the physical properties of X-rays, and the symmetry properties of crystals. The information gained from the studies of crystal structure has already given practical as well as theoretical results of value, but this is to be expected from any properly conducted scientific research, however remote at first may seem the practical side.

It is interesting to note that Sir W. H. Bragg, who has been so actively concerned with research in this line, made it the subject of his address before the Mathematical and Physical Section at the recent meeting of the British

Association for the Advancement of Science. Bragg points out that by means of the X-ray methods a new classification of crystals has been made possible. Previous to the application of the new method, crystals could be classified only by their external form, but now that the internal arrangements are elucidated it has been possible to establish thirty-two classes, according to the internal symmetry displayed. This internal arrangement is, of course, beyond human vision, and out of range of the lens or goniometer. It brings into prominence the "chemistry of the solid," richer as Bragg says "in its variety even than the chemistry studied for the past century."

As a great deal of the work in this field (as is unfortunately true in many other lines of science) exists in foreign languages, the present book will be of great use to the English-speaking students. HENRY LEFFMANN.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS. Report No. 188, Influence of the Form of a Wooden Beam on its Stiffness and Strength. III. Stresses in Wood Members Subjected to Combined Column and Beam Action, by J. A. Newlin and G. W. Trayer. 13 pages, illustrations, quarto. Washington, Government Printing Office, 1924.

This publication is one of a series of three reports prepared by the Forest Products Laboratory of the Department of Agriculture for publication by the Committee. The purpose of these papers is to make known the results of tests to determine the properties of wing beams of standard and proposed sections, conducted by the Forest Products Laboratory and financed by the Army and the Navy.

The purpose of this investigation was primarily to determine the stress which would occur at maximum load. It was found that this stress is dependent not only upon the ratio of bending and compressive stresses but also upon the stiffness of the member, therefore, upon the slenderness ratio. The investigation also involved a consideration of the variation of maximum stress and particularly of the fibre stress at elastic limit.

In actual tests the maximum stress was, in general, considerably higher than the straight line assumed by the Army and Navy and the stress at maximum load somewhat below.

In some cases the stress at maximum load may be considerably below the straight-line relation generally assumed for maximum stress. However, when stress values from the two curves are taken for any ratio of bending unit stress to total unit stress and placed in the ordinary formula, the estimated loads are not reduced proportionally.

A maximum load chart for members of any length and with any form factor was made for Sitka spruce at 15 per cent. moisture. The analysis in this report will show how, for other species, similar charts may be prepared.

Report No. 191, Elements of the Wing Section Theory and of the Wing Theory, by Max M. Munk. 25 pages, illustrations, quarto. Washington, Government Printing Office, 1924.

Report No. 191 contains those results of the theory of wings and of wing sections which are of immediate practical value. They are proven and demonstrated by the use of the simple conceptions of "kinetic energy" and "momentum" only, familiar to every engineer and not by introducing "isogonal transformations" and "vortices," which latter mathematical methods are not

essential to the theory and better are used only in papers intended for mathematicians and special experts.

Report No. 193, Pressure Distribution over the Wings of an MB-3 Airplane in Flight, by F. H. Norton. 17 pages, illustrations, quarto. Washington, Government Printing Office, 1924.

The investigation was carried out to determine the distribution of load over the wings of a high-speed airplane under all conditions of flight. In particular it was desired to find the pressure distribution, during level flight, over the portions of the wings in the slipstream and, during violent manœuvers, over the entire wing surface. The research was conducted at Langley Field by the committee at the request of and with funds provided by the Army Air Service.

The method used, similar to that described in N. A. C. A. Report No. 148, consisted in connecting a number of holes in the surface of the wings to recording multiple manometers mounted in the fuselage of the airplane. In this way simultaneous records could be taken on all of the holes for any desired length of time.

The results obtained in this investigation may be briefly summarized as follows:

(1) There occur in the slipstream, in level flight, positive values of lift of 100 lb./sq. ft. at the leading edge of the upper wing and negative values of over 60 lb./sq. ft. on the leading edge of the lower right wing and the trailing edge of the lower left wing. Approximately 80 per cent. of the load at any point is due to reduction of pressure on the upper side, tending to pull the fabric away from the supporting frame.

(2) The values of lift on the ailerons and wing tips in a sharp aileron roll are only slightly greater than in steady flight.

(3) The lift given by the wings when suddenly flattened out of a dive is about 80 per cent. of the total dynamic load on the airplane, the fuselage and tail carrying the remainder. The lift per square foot on the upper and lower wings under these conditions is in the ratio of 4 to 3.

(4) The centre of pressure coefficient on the upper wings remains under all conditions at about 0.30. On the lower wing it varies between 0.53 and 0.32.

(5) The distribution of lift along the span (moments taken about centre line) is substantially equivalent to a uniform distribution under all conditions.

Report No. 194, Investigation of Slipstream Velocity, by J. W. Crowley, Jr. 7 pages, illustrations, quarto. Washington, Government Printing Office, 1924.

These experiments were made by the committee at the request of the Bureau of Aeronautics, Navy Department, to investigate the velocity of the air in the slipstream in horizontal and climbing flight to determine the form of expression giving the slipstream velocity in terms of the airspeed of the airplane. The method used consisted in flying the airplane both on a level course and in climb at full throttle and measuring the slipstream velocity at seven points in the slipstream for the whole speed range of the airplane in both conditions. In general the results show that for both conditions, *i.e.*, horizontal and climbing flights, the relation between the slipstream velocity V_s and airspeed V can be represented by straight lines and consequently the equations are of the form:

$$V_s = mV + b,$$

where m and b are constants.

PUBLICATIONS RECEIVED.

Relativity for Physics Students, by G. B. Jeffery. 151 pages, illustrations, 12mo. New York, E. P. Dutton and Company. Price, $2.40.

La Méthode Générale des Sciences pures et appliquées, par André Lamouche. 298 pages, 8vo. Paris, Gauthier-Villars et Cie., 1924. Price, 30 Francs.

Geochemische Verteilungsgesetze der Elemente, von V. M. Goldschmidt. 17 pages, 8vo. Kristiania, Jacob Dybwad, 1923. II. *Beziehungen Zwischen den Geochemischen Verteilungsgesetzen und dem Bau der Atome.* 37 pages, plate, 8vo. Kristiania, Jacob Dybwad, 1924. III. *Röntgenspektrographische Untersuchungen über die Verteilung der seltenen Erdmetalle in Mineralien*, von V. M. Goldschmidt und L. Thomassen. 58 pages, illustration, 8vo. Kristiania, Jacob Dybwad, 1924.

Telephone and Telegraph Statistics of American Republics, January 1, 1923. 8 pages, illustrations, quarto. New York, American Telephone and Telegraph Company, July 1, 1924.

U. S. Bureau of Standards: Circular No. 100, Nickel and Its Alloys, second edition. 162 pages, illustrations, plates, 8vo. Washington, Government Printing Office, 1924. Scientific Papers, No. 490, Spectra and Critical Potentials of Fifth Group Elements, by Arthur E. Ruark, F. L. Mohler, Paul D. Foote, R. L. Chenault. 26 pages, plate, 8vo. Washington, Government Printing Office, 1924. Technologic Papers, No. 257, Development of a Method for Measurement of Internal Stress in Brass Tubing, by Robert J. Anderson and Everett G. Fahlman. 16 pages, plates, 8vo. Washington, Government Printing Office, 1924. Technologic Papers, No. 258, Strength of Steel Tubing under Combined Column and Transverse Loading, Including Tests of Columns and Beams, by Tom W. Greene. 36 pages, illustrations, plates, 8vo. Washington, Government Printing Office, 1924.

American Engineering Standards Committee, Year Book, 1924. 64 pages, illustrations, quarto. Standardization—What It Is Doing for Industry. Second edition. 23 pages, 12mo. New York, Committee, 1924.

National Advisory Committee for Aeronautics: Technical Notes, No. 198, Micarta Propellers—I. Materials, by F. W. Caldwell and N. S. Clay. 5 pages, illustrations, quarto. Washington, Committee, 1924.

Forest-pest.—*English Mechanics* (1924, **120**, 42) reports that Prussian forests are being most seriously injured by the ravages of the larva of a moth. Pine trees are the species affected, and it is said that over thirty million feet of timber are dead or dying. The moth lays its eggs on the under side of the pine needle. The caterpillars hatch in May and eat their way from the tree top to the bottom. It is reported, however, that they are now dying in large numbers either from a fungous disease or from the attacks of ichneumon flies. Very little seems to have been accomplished by ordinary forestry methods, but one owner has imported a large number of ants and believes that these will save considerable timber by attacking the caterpillars. H. L.

CURRENT TOPICS.

Vitamines in Live-stock Feeding.—If farm animals do not receive the proper vitamines in sufficient amounts, they become unthrifty, and develop certain symptoms such as indigestion, loss of appetite, and nervous disorders, or even certain diseases such as paralysis and rickets. According to H. H. MITCHELL and M. HELEN KEITH (University of Illinois Agricultural College and Experiment Station, Circular 282, 20 pages, 1924), farm animals require fat-soluble A and water-soluble B, but do not require water-soluble C. Exposure to direct sunlight acts as a preventive of rickets, and fat-soluble D, therefore, usually is not required; this preventive action is not exerted by sunlight which has filtered through glass and thereby been deprived of the effective ultra-violet rays. There is little danger of vitamine-deficiency in the rations of cattle, sheep, and horses; more danger of such deficiency exists in the case of swine and poultry. Animals, which consume large amounts of fresh green roughage, good pasture, or well-cured hay, and are kept out-of-doors, probably will never suffer from deficiency of vitamines. Growing swine may at times become unthrifty and diseased as a result of a deficiency of fat-soluble A in the ration; this condition may be removed by use of good pasture or good hay, and by feeding yellow corn instead of white corn. Growing chickens and laying hens have so high a vitamine requirement that an ample supply of green feed and direct sunlight is more important for poultry than for other live stock. Since judicious use of ordinary feeds readily corrects vitamine deficiencies of farm rations, commercial vitamine preparations are not required in stock feeding. J. S. H.

Occurrence of Germanium in Smithsonite and in Mine Waters.—JOHN HUGHES MÜLLER, of the University of Pennsylvania (*Ind. Eng. Chem.*, 1924, **16**, 604–605), has found 0.01 per cent. of germanium dioxide in the smithsonite or native zinc carbonate from the Hudson Mine near Salem, Livingston County, Kentucky. Hitherto germanium has been found only in blendes or sulphide ores of certain metals, chiefly zinc, copper, and silver. The smithsonite from the Hudson Mine is practically free from arsenic and lead. Germanium is present also in the water of this mine, the non-volatile total solids obtained from the water containing 0.29 per cent. of germanium dioxide. The mine water is used in washing the ore; the non-volatile total solids obtained from the wash water were found to contain approximately 0.5 per cent. of germanium dioxide. In working this ore, waste zinc oxide is obtained from the furnace flues and pipes; it contains 0.01 per cent. of germanium dioxide. This waste

material is used for the manufacture of zinc sulphate. Germanium dioxide may be recovered from the mother liquor after crystallization of the zinc sulphate. In this manner, 2.75 grams of pure germanium dioxide were recovered from 100 pounds of waste zinc oxide.

J. S. H.

IN Great Britain it has not infrequently been the case that important scientific advances have been made by men of the professions or of business. Thus Gilbert was Queen Elizabeth's physician, Sir Charles Wheatstone was a lawyer and James P. Joule, a brewer. At the British Association in Toronto Sir Richard Paget, Bart., a specialist on the legal aspects of inventions, presented a formal paper on "The Nature of Speech" and at the Converzatione delivered a "lecturette" on the same subject. On page 740 of this JOURNAL for June is to be found a statement of his theory of the production of vowel sounds, *viz.*, that such sounds are characterized by the presence of two notes of different pitch produced by the passage of air through two vocal cavities in series. These cavities are separated by the tongue. "By your tongue you vary the waist-line of your mouth." He demonstrated his ability to vary the dimensions and hence the resultant note of one of the cavities while he maintained the note of the other without change. Moreover, he varied their pitches simultaneously, producing a series of compound sounds with his mouth, wherein the pitch of the sounds from one cavity progressively rose while that from the other fell.

The two components of the vowel sounds of "hat" and of "put" are about the same number of semitones apart in pitch. He had a dictophone record of the "a" sound. When the speed of rotation was reduced to about five-ninths of its former amount the emitted vowel became the "u" sound. He claims that a certain component of high pitch represents the American contribution to vowel sounds, and successfully imitates the nasal quality by the passage of air through a third cavity in series with the other two. The additional pitch is due to 2400 vibrations per second and is not really nasal in origin but is caused by a constriction of the pharynx. He emphasized the musical advantages of voiced over unvoiced sounds, calling attention to the lack of the latter in the dialect of his shire of Somerset.

In the less formal talk at the Converzatione he showed that it is possible to whistle a note of one pitch and at the same time to hum a note of another. He and his daughter, Lady Sylvia, gave a quartette in which he produced the alto and bass, while she rendered the other two parts. At the same entertainment he exhibited his dog, "Radio Rex." This is a toy animal that is held in a kennel by the pull of an electromagnet, energized by an electric current. In the mechanism is a part whose natural frequency of vibration is 500 per second. When a sound of this periodicity is produced the part is set in sympathetic vibration, the current is interrupted and a spring, no longer overcome by the electromagnet, shoots the dog out of his box.

The vowel of "Rex" has a component of the requisite frequency, so that the call of the word is followed with surprising promptness by the appearance of the dog, while the utterance of other names produces no effect, unless they, too, have a component of the right pitch. At the close Sir Richard placed in his mouth a rubber tube and, blowing through it, set in vibration a membrane that emitted a squeaky noise into a space enclosed by his hands. He then by the use of his fingers divided this into two cavities for the enunciation of vowels, and opened and closed the space in such a way that consonants were produced. Thus manipulating the "cheirophone" he made it say, "I hope you have all enjoyed this paper." G. F. S.

MR. P. D. FOOTE of the Bureau of Standards suggests arsenic vapor traversed by an electric current as a source of ultra-violet light. No visible radiation is thus produced. G. F. S.

PROF. H. N. RUSSELL, of Princeton, in a paper on the "Spectrum of Titanium" at the British Association, stated that from a study of the stars it can be inferred that helium has a high and titanium a low ionizing potential. In connection with the difficulty he experienced in disentangling the complex relations of the spectral lines of this element, he recommended in similar cases that the investigator drop his problem for a week and then return to it afresh.

In the course of his remarks he made reference to work of investigation done by some one in Spain. It would therefore appear that this country is advancing in science, for in recent years scarcely any physical papers have originated there with the exception of those emanating from the pupils of Pierre Weiss, the originator of the magneton theory of magnetism. G. F. S.

AT THE British Association Sir Napier Shaw presented a paper, "If the Earth Went Dry." He manifestly found pleasure in the double meaning that might be attached to this title. One of the effects would be the nearer approach to the earth of the surface separating the lower region where convective air currents hold sway from that above it where the temperature does not vary with height. He appeared to feel that as a rule people are not sufficiently impressed by the magnitude of the radiation received by the sun, which he stated to be equal to 5000 kilowatts per acre. Professor Eve, of McGill University, was presiding at this session, and at the close of the paper expressed his personal indebtedness to the distinguished author for having sent him, a man brought up on books, two original papers in Cambridge University. G. F. S.

P. E. SABINE, of the Wallace Clement Sabine Laboratory, Riverbank, Geneva, Illinois, read a paper before the British Association on "Research in Architectural Acoustics." It was very appropriate that a paper on this subject should emanate from a member of the Sabine clan. In the sound chamber of his laboratory the measure-

ments are made with such accuracy that the presence in the room of an additional square-foot of carpet can be detected by the change it causes in the length of time during which sounds there reverberate. He announces as the result of his experiments made on some fifteen masonry walls of different materials and of different thicknesses that the "general reduction of sound in transmission through such walls is independent of the material and the structural stiffness of the wall, and is a function only of the weight per unit area."

C. A. Chant, Professor of Astrophysics, Toronto University, thus interprets this conclusion: "It is sometimes thought that a wall of sawdust or cork is a good insulator of sound, but such is not the case. The partitions which allow least sound to pass through them are those which have most weight per square foot of area. Thus a wall of stone one foot thick is more impervious to sound than one of wood five times as thick." G. F. S.

AT THE recent meeting of the British Association at Toronto the following cryptic notice was to be seen in the registration room: "Red Lion Club. The supply of bones being limited, Lions revisiting the Den should scratch a line forthwith to the Jackal Poste Restante, Reception Room." This organization originated in 1839 and was due to the desire of some to escape from lavish and formal hospitality to a quieter and more genial atmosphere. The ritual required that members upon rising to speak should roar and flourish their coat-tails. The meetings have at times been of compelling interest, for on one occasion Sir Joseph Dalton Hooker, President of the British Association in 1868, drank a wine-glassful of ink before he discovered the presence of the pen with which he should have signed the attendance book. G. F. S.

WHEN Sir William Bragg had finished his address as President of Section A of the British Association, Sir Ernest Rutherford arose and, after remarking that on such an occasion "it is the custom for one of the ancients to say something," proceeded to speak in a complimentary manner of the communication just ended. Prof. W. Duane, now of Harvard, seconded Sir Ernest's remarks. Then came a scientific conjunction that rarely occurs. The next speaker was W. L. Bragg, the son of the president of the section, and, like his father, a Fellow of the Royal Society, and his paper like that of his father dealt with the physical properties of crystals, especially with the application of X-rays to the determination of crystal constants. He began by calling attention to the vast amount of optical information about crystals that remains to be exploited, and then went about showing how it can be utilized. "When an electromagnetic wave passes through a medium the electric field polarizes the atoms, their positive and negative components being displaced from the normal configuration. This creates an electric field around each atom equivalent to that of an electric doublet whose moment is proportional to the electric vector at each instant. The velocity of the wave

in the crystal depends on the ratio between the total polarization per unit volume and the field. Each atom is affected by the general field and by its polarized neighbors. In a crystal which has been analyzed by X-rays the effect of neighboring atoms on each other can be calculated. The double refraction of calcite and aragonite, for instance, can be satisfactorily explained quantitatively." Suppose that the electrical vector of the wave is perpendicular to this page, lying in a horizontal plane, at the point X, and that A, B and C represent three similar atoms, such as the three atoms of oxygen in calcite, in a plane at right angles to the vector— $\begin{matrix} AO & OB \\ & X \\ & OC \end{matrix}$ then the effect of the wave will be to produce positive electrical charges on the upper, and negative charges on the lower sides of the atoms. The mutual repulsion of the positive charges on the three upper parts and of the negative charges on the lower parts is equivalent to a sort of elastic stiffening of the medium transmitting the wave. On the other hand, let us consider what is the case when the three atoms are not in the same horizontal plane, but when A and B are higher up than C, that is, when the page is turned into a vertical position. The vector is supposed to be still vertical. In this new arrangement the lower side of A and B will have a negative charge while the upper side of C, which is nearer to them, has a positive charge. We now have attraction between adjacent charges and the shifting of charges that accompanies the passage of an electromagnetic wave will be retarded by this conservative force; in other words, the wave is of less velocity than in the former arrangement. In calcite the three oxygen atoms are in a plane perpendicular to the optical axis. Accordingly the wave velocity is greater when the electrical vector is along this axis than when it is perpendicular to it.

The fast ray in calcite has a refractive index of 1.49 and the slow ray of 1.66. The corresponding calculated values are 1.49 and 1.63. From a study of double refraction in crystals, it is possible to compute the distance between atoms. Later Professor Bragg hopes to bring the rotation of the plane of polarization within the range of calculation.

He exhibited a magnetic model that illustrated the different vibration periods due to different arrangements. Three magnets were supported at points A, B, and C in such a way as to hang always vertical or to swing about a horizontal axis, with the same poles uppermost in all three. When A, B and C were in the same horizontal plane one of the magnets being displaced, executed more vibrations in a second than it did when the triangle of the magnets was turned so that its plane was vertical. G. F. S.

On the Luminescence of Nitrogen, Argon and Other Condensed Gases at Very Low Temperatures. J. C. MCLENNAN and G. M. SHRUM. (*Proc. of the Royal Society*, A736.)—There are two cryogenic laboratories in the world in the universities of Utrecht and

Toronto. A few months ago it seemed that from the former had come the solution of the problem of the origin of the famous green line in the light of the aurora. (See this JOURNAL, Aug., 1924, p. 275.) Vegard reported that he had found this line in the spectrum of the light emitted by solid nitrogen under the bombardment of cathode rays. Four months later Section A of the British Association held its meeting in the physics building of the University of Toronto, which houses the second cryogenic laboratory. It was thus possible for Professor McLennan to show the freezing of a tube of liquid air by immersion in liquid hydrogen and the solidification of hydrogen due to the reduction of temperature produced by the boiling under lowered pressure of the liquid of this element. On another day liquid helium was displayed. Still another exhibit was the beautiful green light given off by solid nitrogen subjected to cathode rays. This very striking experiment was, however, accompanied by the statement that investigations made by Professor McLennan and Doctor Shrum flatly contradicted the findings of Vegard. The details of their investigation are given in their Royal Society paper. After the bombardment of the solid nitrogen by cathode rays had ceased, the solid phosphoresced for several minutes with green light consisting of a single wave-length, 5231.2 Å. While the rays were still impinging, a brilliant yellow-green light was emitted in addition to the phosphorescent light just mentioned. "The analysis showed this light to be characterized by three broad lines or narrow bands at $\lambda = 5556$ Å., $\lambda = 5617$ Å., $\lambda = 5654$ Å.; the intensities being approximately 50, 10, and 7, respectively. Many photographs of this light were taken and the wave-lengths were checked very carefully. A line at $\lambda = 5577$ Å. corresponding to the auroral green line never came out on the plates in any of the experiments." For comparison a tin spectrum was photographed parallel to the spectrum from solid nitrogen. The wave-length 5577 fell just between two of the lines of tin. The writer had the opportunity of examining this plate and noted that there was no trace of a line of this wave-length on the nitrogen spectrum. It may have been that Vegard used so wide a slit that the three lines overlapped to produce one wide line that covered 5577. It is worth remembering that in the Toronto investigation these three lines were got while the nitrogen was evaporating and re-crystallizing at $-252°$ C. Argon was examined in the same way. Its phosphorescent light lasts only a few seconds after the cessation of the rays.

Because of similarities between nitrogen and carbon monoxide in spectra and in other physical properties, pointed out by Nagaoka and Langmuir, it was worth while to test solid CO under the same conditions as solid nitrogen. "Solid carbon monoxide, ammonia, oxygen and water vapor did not phosphoresce and did not become luminescent under irradiation by electrons at the temperature of liquid hydrogen. The authors are forced to the conclusion" that "the

origin of the auroral green line cannot as yet be definitely connected with the elements nitrogen or argon. Our experiments, as carried out so far, do not preclude the possibility of the auroral green line having its origin in some lighter element—in solid hydrogen—or in very cold luminous hydrogen, or helium or hydrogen-helium vapors, for example, provided the proper mode of excitation is used." Thus the green line of the aurora is relegated for the present to the group of lines of unknown origin that includes a line proceeding from the corona and certain lines from nebulæ. We must surrender further, at least for the present, any belief we may have acquired in the presence of solid nitrogen in the upper air and with it must go the associated explanation of the twinkling of the stars given in *Le Matin* last June by Charles Nordmann.

At the close of his lecture before the International Mathematical Congress on "Modern Norwegian Researches on the Aurora Borealis," Prof. Carl Störmer quite properly stated that on the question at issue between Vegard on the one hand, and McLennan and Shrum on the other, he reserved judgment until further data be obtained. G. F. S.

A Synopsis of the Ionization Potentials of the Elements. CECILIA H. PAYNE, Harvard College Observatory. (*Proc. National Academy of Sciences,* July, 1924.)—A valuable tabulation of the ionizing potentials of 42 elements is given with the method, whether physical, spectroscopic or astrophysical, and reference to the original papers. "The possibility of making astrophysical estimates of ionization potential is a direct result of the Saha theory of ionization in stellar atmospheres. It appears, from the success with which this theory has accounted for the chief features of stellar spectra, that Saha's basic assumption that thermal ionization can be treated as a type of chemical dissociation is fully justified. The fundamental formula, which is essentially the Law of Mass Action, regards the ionization potential as the latent heat of evaporation of the electron from the atom or molecule."

The ionization potentials of the elements are plotted as ordinates against the columns of the periodic table, which contain the elements, as abscissæ. When the elements are studied by periods very interesting relations are discerned between their ionization potentials.

G. F. S.

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